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AUSTRALIAN ELECTRONICS Monthly

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AUSTRALIAN MADE

WHAT AN EXCITING YEAR we have to look forward to! While our bicentenary is being celebrated in so many exciting ways and places around the nation, we have some exciting plans and publishing projects to unfold in the coming twelve months.

To kick off, this month we have the first article in the Novix Super Microcomputer project – first mooted over 12 months ago. What was basically a "kite-flying" exercise then is now a reality – an affordable, build-it-yourself computer project with more computing power and speed than current industry standard minicomputers. For those age-hardened hackers who remember the eager excitement of the early days of the microprocessor, here is "the unattainable" come true!

For the confirmed audio enthusiast, this month's leading Star Project, from Scan Audio in Melbourne, is a superb four-way hi-fi loudspeaker set featuring a set of top-quality Dynaudio drivers. These speakers deliver performance rivalling commercial models costing up to three times the kit price. If you're handy at woodworking and cabinet construction, you can save even more money by building your own boxes.

Next month, we plan to present a VHF satellite receiver for those enthusiasts, teachers and students keen to "join in the space age". This unit is designed to receive the transmissions from the polar-orbiting weather satellites on the 136-138 MHz band or the University of Surrey "UoSat" craft transmitting around 145 MHz on the two metre amateur band. We've published decoders for both satellite series in the past, and we've described suitable antennas, too. So, once we've published this receiver, you'll be able to assemble your own satellite ground station and truly join in the space age.

And our plans don't stop there, but that's enough for the moment.

This month, our popular Semiconductor Scene column does not appear due to lack of space, for which we must apologise. However, it will return next month. Doubtless you'll find plenty else to read anyway!

Roger

Roger Harrison
Editor

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COVER

Build the Profile 4, a top quality 4-way bass reflex speaker featuring Dynaudio drivers. Photo courtesy of the distributors, Scan Audio. Design, Val Harrison.

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AEM4000 The SuperMicro!
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Faster than a speeding VAX, more powerful than a . . . what the heck – read it and believe it, the most fantastic computer project yet published! Based on the powerful Novix NC-series "Forth Engine" this is the project we've talked about for the past year.

AEM4511 MIDI Interface for the Microbee
. . . . . **60**

Build this "musical instrument digital interface" and get your MIDI system act together! This unit is simple, economical and you can drive it with a low-cost Microbee.

STAR PROJECT No.1
The Profile 4, Dynaudio 4-way Loudspeaker
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STAR PROJECT No.2
A Stand-Alone Morse/ RTTY Decoder
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Got a shortwave receiver? Plug this decoder into the audio output, then plug in a low-cost printer and you can decode Morse code and radio teletype transmissions.

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Filter Design – without fears or tears. Part 3
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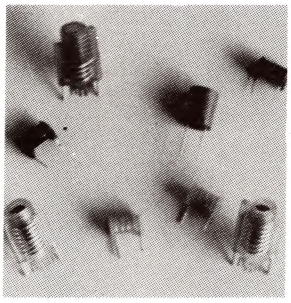
Jack Middlehurst inducts us into the mysteries of elliptic filters.



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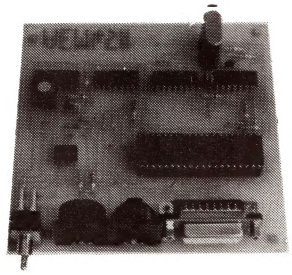

MIDI-Computer Interface
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Bring that MIDI music system into line using a Microbee and our interface project.

A Mystery Solved – PBUFF Explained
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The PBUFF 256K Printer Buffer project employed a few neat Z80 software tricks to address all that RAM without hardware support. Here's how it was done.

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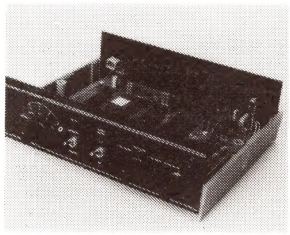
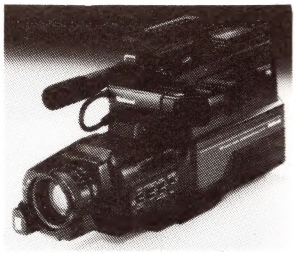
Dust-off the DX gear, the sunspot numbers are rising fast and the indications are looking good for an exciting peak!



Build a "Stand-Alone" Morse/RTTY Decoder 65

Take your shortwave receiver, a low-cost printer and add this great project – a recipe to satisfy your hunger for the fruits of a great bunch of non-voice transmissions on the HF bands.

CONSUMER ELECTRONICS



National's "Stop-Motion" Video Camcorder – the M5 12

This unique video camcorder sports a "1/1000th-second shutter" enabling "stop-motion" recording without blur.

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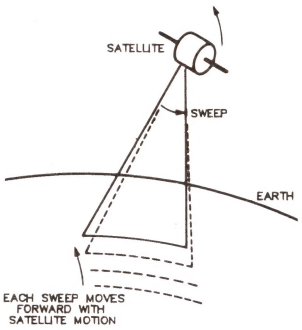
NOTES & ERRATA

In the AEM4601 Baud Rate Converter, Nov. '87, on the overlay on page 72, the annotation for R1(2k2) and R3(1k) was transposed. Fortunately, this had little real effect on the unit as the circuit still operates with these resistors transposed.

NEXT MONTH!



VHF RECEIVER FOR THE WEATHER SATELLITES OR UOSAT

Build your own satellite ground station! Here's a fairly simple, but nonetheless effective receiver that is readily used for either reception of the polar orbiting weather satellites around 136-137 MHz or the UoSat craft on 145 MHz. Now you can assemble your own satellite ground station using all AEM projects!

CLEANING UP THE MAINS

Spikes, hash, brownouts and other assorted "ills" – they can all play havoc with mains operated instruments, computers, receivers – most electronic equipment, in fact. Here's a run-down on causes and cures.

EQUALIZATION – THE TOOLS & TECHNIQUES

A look at the various equalizer types from two-knob units through graphics to parametrics, and how they're used.

LISTENING POST SOFTWARE FOR THE IBM & CLONES

Here it is! After so many requests for software to use our very popular AEM3500 Listening Post project on IBM and compatible computers, a reader has come up with some very snazzy software. Now you can decode and display or print all those fascinating FAX, Morse and radioteletype transmissions on the shortwave bands.

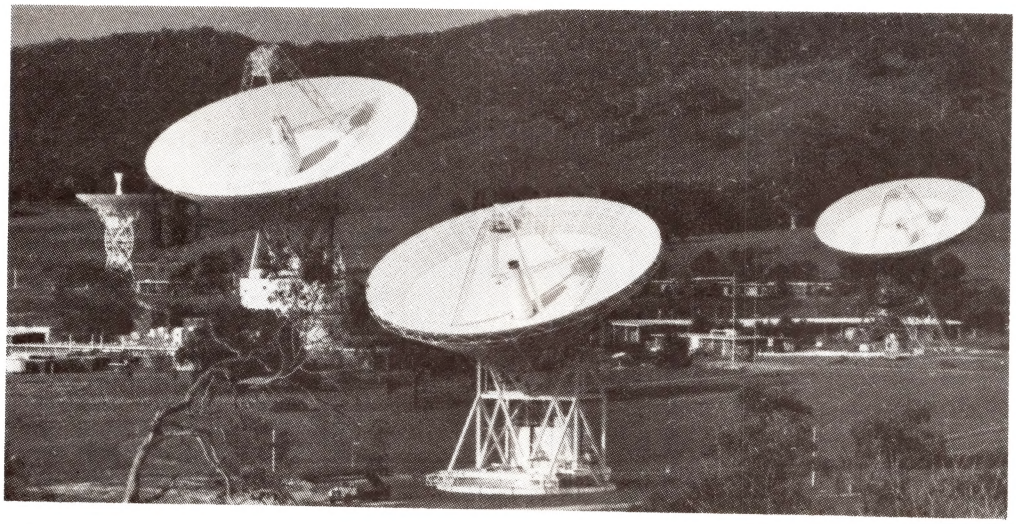
While these articles are currently being prepared for publication, unforeseen circumstances may affect the final contents of the issue.

FEATURE

The Berlin Audio/Video Fair 8

A false start for DAT, while Video 8 steals a march. And CD-Video? – "marriage between an elephant and a princess!"

AWA completes deep space station rebuild



Amalgamated Wireless (Australasia) Limited (AWA), has completed a $5.5 million contract to rebuild Australia's largest deep space station.

The antenna, known as DSS43, is the centrepiece of the Canberra Deep Space Communications Complex (CDSCC) at Tidbinbilla near Canberra.

It stands about as high as a 20-storey building, topped by a steel and aluminium dish nearly the size of a football field.

The rebuild involved expanding the diameter of the 3000 tonne dish from 64 metres to 70 metres in preparation for the Neptune Encounter in 1989, when the Voyager II spacecraft passes close by the distant planet Neptune.

Timing for the reconstruction of the antenna was critical. The giant dish had been used as the primary communications link to Voyager II during the Uranus Encounter last year. It also tracked the European Space Agency's Giotto spacecraft which flew past the nucleus of Halley's Comet.

As soon as these tasks were completed, work began on the reconstruction of the dish. The deadline was to have the dish operational late this year to begin the lengthy preparations for Voyager II's encounter with Neptune.

The 64 metre diameter dish has been expanded by six metres to enhance reception of the faint signals from the Voyager II spacecraft, now more than three thousand million kilometres from Earth.

The precision of the job is quite staggering, the maximum difference between the high points and pits over the entire surface of the dish being only 0.6 millimetres.

Radio signals transmitted from the Tidbinbilla site now take more than two hours 45 minutes to reach the spacecraft! The signals received from Voyager II are reflected from the dish's surface to a cryogenically cooled receiver and the centre of the antenna. The superconductive receiver is kept at a temperature of about minus 270 degrees Celsius – as close as possible to absolute zero.

CDSCC is funded by the US National Aeronautical and Space Administration (NASA) and is managed by the Commonwealth Department of Industry, Technology and Commerce. AWA holds the current contract for operation and maintenance services and all but three of the 170 staff at the centre are AWA employees.

Philips & Sony agree on CD write-once system

Philips and Sony have announced that they have agreed on basic specifications for a compact disc (CD) write-once system intended for professional applications.

Based on the compact disc standard jointly developed by Philips and Sony, the CD write-once recorder permits one time digital recording of data or audio information onto a blank write-once disc. This information can the be read repeatedly by using a CD write-once recorder.

New specifications such as groove and tracking characteristics, which are necessary for writing onto optical discs, have been added to the basic CD specifications.

The two companies expect that the CD write-once system will serve as an extension of CD-ROM (Read-Only Memory), as well as having applications in professional audio recording. A data storage CD write-once system would also be able to play conventional CD-ROM discs whilst a professional audio CD write-once system could play conventional CD audio discs.

Philips and Sony will continue to co-operate on finalising the detailed specifications, with the anticipated date for release to licencees being early 1988.

CAD software grants from Autodesk

Autodesk Australia Pty Ltd, the newly formed subsidiary of Autodesk Incorporated, has announced the launch of their Autodesk Grants Program. Modelled along the lines of the parent company's programme, Autodesk Australia will award in excess of $1 million worth of CAD software products during 1987-88.

The grants will not be limited to government funded groups. Private individuals, students, teachers, institutions, R&D groups, libraries, etc. will all be eligible for participation in the programme.

In order to be considered for a grant, registration of interest (in writing) must first be lodged with Autodesk Australia. Autodesk will then forward an application form and conditions of the programme.

Applicants will be asked to provide an outline of their current and projected CAD needs and skills as well as a brief summary of how and when they would put the software to use.

For further information, contact **Julie Volpe, Autodesk Australia, PO Box 458, Richmond 3121 Vic.**

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TL072CDP	100	0.65
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TL082CDP	100	0.65
TL084CDP	100	1.00
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A false start for DAT, while Video 8 steals a march

Dennis Lingane

Our roving correspondent, Dennis Lingane, attended the International Hi-Fi, Video and Broadcasting show held in Berlin during September this year. Dennis sent us this report of what the "movers and shakers" in the consumer electronics market are up to.

THE BERLIN AUDIO/VIDEO FAIR, called the Internationale Funkausstellung by the locals, is held over a two week period and attract over 400 000 people. Filling 25 pavillions, there are 365 exhibitors from 26 countries, making it easily the largest show if its kind in the world.

Most of the dealers and industry pundits attending the show spent their evenings in the Berlin bier kellers, trying to analyse what on earth the Japanese, the undisputed captains of the electronics industry, are up to.

DAT – a camel?

As an example, Sony, who have a massive commitment to compact disc and 8 mm video, launched the controversial DAT system on the eve of the show. This surprise announcement was expected to panic other manufacturers into announcing release dates for their DAT machines, but everyone refused to either announce dates or even comment on the Sony move. Even JVC, which had a large DAT presentation at the show, complete with dancing girls, lights and smoke effects, refused to say when it would release DAT on the world market.

There were a couple of reasons given for this lack of enthusiasm by these Japanese companies to release DAT. Philips say it is because the industry has found incompatibility between the different brands – a tape recorded on one machine does not always play on others. This statement was denied by some companies, whilst from others, there was "no comment".

A more reasonable explanation came from the ebullient and outspoken executive from BASF, Bill Andriessen, who was a member of the international committee that agreed on the design parameters for DAT. He says: "The DAT has died a death in Japan. The manufacturers are trying to work out why. I can tell them, in fact I told them two years ago when we settled on the design – it is a camel. It offers nothing new to the consumer – so why should they buy it?"

Andriessen says that only when the DAT cassette decks are designed to be "recording robots" will they have a chance in the market place. "You would think that the Japanese would learn from their video industry, but the video engineers do not talk to the audio engineers in the Japanese multi-national companies. Instead of making a DAT machine like a VCR to enable consumers to record FM programmes when they are away from home, they make a machine that is like all other audio cassette machines and at ten times the price. How can it sell?"

He says that even if the Japanese re-design the DAT machine and launch it properly he predicts that it will only ever gain 10 percent of the market share.

"Compact cassette is too well entrenched," he said. "There are now 500 million cassette machines in homes around the world compared to 200 million record players and 25 million compact disc players. To try and convert all those people to a new cassette system is impossible. It will only appeal to audio buffs."

BASF are making the tapes for DAT machines but outspoken company executive, Bill Andriessen, maintains DAT will only appeal to audio buffs.

I managed to listen to the Sony DAT player and wondered what all the fuss was about. If hi-fi and music enthusiasts thought that the early compact disc players were harsh, wait until they hear this – it was abominable! Time might cure this as it did with CD, and one must not rule out the possibility that Sony had a bad tape, but if one is to take the demonstration on face value, the sound is really poor."

Video 8 steals a march

On the video side, the pundits are predicting that in the mini-camcorder stakes, Sony will be the winner with its 8 mm system. It is already outselling the VHS-C system with around 57 per cent of the market. If the Sony 8 mm system does become the world standard for portable/mobile entertainment, it will mean that Sony will be free to switch to manufacturing VHS. It will have gained some kudos to sweeten the humble pie it would have to eat in finally conceding to the domination of VHS.

Currently Sony only makes up-market Beta machines for the technically aware. It is missing out on the mass market by not being in the VHS camp and even a quality image company like Sony would like to be in that cash flow market. The only hope that JVC has to head off the 8 mm win is to bring a Super VHS-C system to the market quickly. They could do

this quite easily in a camcorder, while it would be very difficult in a mains powered machine, say industry engineers.

The Super VHS system is already released in the USA which has a different and more simple system than that used in Australia. The Super VHS has a sharper and more colourful picture, achieved by splitting the signal into its basic parts, chrominance and luminance. Each of these is enhanced separately and then combined to form the complete TV picture.

This higher picture quality is important to photographers because they want to edit and transfer from tape to tape to create a home movie. With each transfer, there is a loss of quality so it is vital to have a very good picture to start with. For this reason, a Super VHS camcorder would be extremely popular with video photographers.

Thumbs-down on CD-Video

CD-Video was the only other main area of discussion over the litres of Berlin Kindl Bier consumed nightly. It has generally been given a thumbs-down by the dealers, who see it as just another re-launch of video disc. That is all it really is – a miniature video disc the same size as a compact disc, but with six minutes of video clips and 20 minutes of digital audio.

Many CD-Video machines on display at the show were similar to the Pioneer Kombi video disc players already available in the USA and Japan. This is a video disc machine that will also play compact disc and mini video disc. There has been a problem developing a similar machine for the PAL markets like Europe and Australia because the PAL signal is much wider and takes up more space. This has now been conquered however, and Philips says that its first CD-video disc Kombi player which was unveiled at the show will be released in a couple of months. They say that a mini player to take only CD and CD-video discs is not on the drawing board.

Other manufacturers also showed 30 cm video disc players that would also play compact discs, so CD-video, when it is finally launched, could be something of an anti-climax if it is tied to the coat tails of video disc. BASF's Andriessen, who is never lost for words, says CD-Video is "a marriage between an elephant and a princess"

"It has no application in the market," he says. "The compact disc is popular with music lovers. One only has to look at the sales of classical music, much of it analogue recordings transferred to CD, to realise that the system is a success because of its musical following. These consumers won't want video clips."

Car electronics

One other area worth reporting is car electronics. Sony showed a prototype of a car DAT player, but everyone else was offering car radios that have large TV style display panels. When the radio is tuned into a local FM station on its automatic scanning system, the frequency and callsign is displayed on the screen so you can see at a glance who you are tuned to.

The engineers have also concentrated on making the sophisticated and therefore more desirable in-car equipment theft proof. They have removable control panels that fit onto swan-neck stalks in the car cockpit. This control panel is no larger than a calculator and so can be dropped into a handbag or pocket. The PIN (Personal Identity Number) is also very popular. If the radio is disconnected from the battery for any time, it can not be used again until a secret code has been fed into the unit. Anyone taking one of these radio cassette players in fact ends up with nothing more than a box of useless electronics.

Technics grabbed a lot of limelight with a new speaker system the size of a house wall. It has a number of flat drivers and looks like a space-age mural instead of a speaker. What did it sound like? No comment.

Another company showed neon phones, speakers and radios. the speaker boxes and radios are made out of clear acrylic and have neon lights inside. The effect is a futuristic sound system that is a cross between inexpensive house lighting and art-light.

It appears that with little else happening in electronics, the industry is resorting to gimmicks and fashion to maintain the consumer interest in the industry.

Sheffield Labs select TDK MA-X Finavinx for their Reference Recording Series

Sheffield Laboratories, world famous producers of high quality recordings, has moved into production of quality audio cassettes using TDK MA-X tapes for their new "Reference Recording Series" cassettes.

Sheffield Laboratories is a US company which specialises in production of special high quality vinyl records, high quality compact disc and now, high quality pre-recorded audio cassettes.

The Sheffield Labs' Reference Recording Series cassettes are produced from live, unedited two track analogue reference tapes recorded simultaneously during the original direct disc performances. The cassettes are duplicated on Nakamichi ZX-9 decks using exclusively TDK's metal tape.

TDK utilise a pure iron magnetic particle formulation known as Finavinx. These pure iron particles, with a total absence of oxygen, produce a magnetic coating which is wholly magnetizable. TDK claim Finavinx has four times the magnetic energy of high (chrome) position tapes.

It is these special properties offering high retentivity and coercivity that make Finavinx such an ideal storage medium, says TDK. Its ability to accept a wide range of musical energy without saturating means that exactness of recording levels is not so critical.

TDK's MA-XG is housed in a world famous RS-II (reference Standard II) mechanism, utilising a three layer construction, which TDK claim, offers the smoothest tape transportation system on the market today.

Pioneer tunes into top end

Pioneer has definitely tuned into the right wavelength with the release of it's three newest digital tuners. The tuners represent a continuity of design, matching with other components of Pioneer's range and featuring the highest quality components to provide the latest in digital audio technology, they say.

The new range is headed by the F-91 Reference Digital Synthesised Tuner which features Active Real-Time Tracing System (ARTS) – an active IF filter that follows the tuned frequency to capture the desired signal whilst blocking out interference.

The unit also contains a Digital Direct Decoder (DDD) type 111, to further improve every major tuner specification and a PLL detector to improve the signal-to-noise ratio. The F-91 can also randomly pre-set 24 AM/FM stations and has a three programme memory for other functions such as time-set.

Also part of the new releases is the F-717L which features DDD as well as Pioneer's "pulse swallow" frequency synthesis function which, using an ultrasonic reference frequency, provides stable reception and a high signal-to-noise ratio.

The F-717L can pre-set up to 16 FM/AM stations which can be recalled at a touch whilst a large loop antenna and an FET buffer for the tuning coil ensure clean AM sound.

Pioneer claim their new audio components range is the most extensive and exciting series yet produced by the company and represents it's continued push towards obtaining the best possible sound quality and performance. For further information on these and other products in the range, contact your nearest Pioneer dealer.

Compact 3-way speaker from Rebel

Rebel Audio has introduced the Community CS52, said to be an ideal choice for either live sound reinforcement or playback/monitoring applications.

The CS52 combines high sensitivity and power handling capabilities with smooth response and low distortion to form the latest addition to the CS series of loudspeaker systems made by the American company, Community Light and Sound Inc.

The 3-way CS52 has a bandwidth running from 40 Hz to 20 kHz and features uniform wide-angle dispersion and a coherent wavefront design allowing for precise time performance, the makers claim.

The CS52's tough enclosure gives it roadworthy durability to withstand even the most arduous tours. The enclosure is made from rigidly braced particle board covered with with rugged black carpet. An Acoustically transparent steel mesh black grille complements the front of the cabinet, while portability is enhanced by steel bar handles.

Like all other CS series models, the CS52 incorporates fuseless protection circuits to guard against excessive input levels.

Further information from **Rebel Audio Pty Ltd, 104-106 Hampden Road, Five Dock 2046 NSW. (02)713 6866.**

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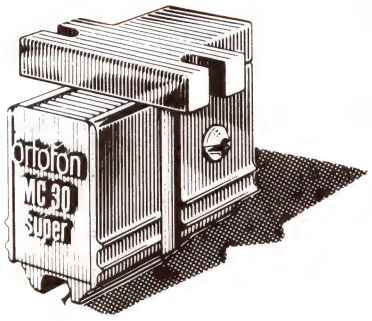

Many people have been mass-marketed into believing that digital 'music' is superior to analogue reproduction. This new ORTOFON MC-30 Super Cartridge will most certainly show you where this theory goes completely wrong! Using pure silver wiring, Ortophase phase/amplitude linearity and a pure platinium damping disc, the ORTOFON MC-30 Super delivers directly to both ears the superior musicality of high-class analogue reproduction. As others have already said:

"... the overall sound is one of extreme clarity which can bear comparison with CD at its best. In fact, unlike CD players, a well designed moving-coil cartridge like this one maintains its response well beyond the 20kHz upper limit."

John Borwick, Grammophone, April 1987.

"The MC-30 Super is a better cartridge than most of its rivals. It's just a thoroughly musical design, and there's little that needs to be added to that bald statement. Go for this cartridge if you want a sharp, incisive sound of real refinement and with explicit stereo."

Alvin Gold, HI-FI Answers, April 1987.

"The MC-30 Super ... is the child of a mating of the MC-20 Super and the MC-2000 – both of which I know and adore. Once the cartridge bedded in, it was as sweet as sugar, an MC-2000 without the bite and with most of the detail ... Ortofon has plenty of reasons to believe that a market for high quality cartridges still exists, and this continued support of the LP has resulted in an outstanding transducer."

Ken Kessler, HI-FI News and Record Review, March 1987.

"The MC-30 Super is a superlative tracker ... Highs are gorgeous – smooth, open, and sparklingly crisp ... Low-frequency performance, too, is excellent."

J. Gordon Holt, Stereophile, January 1987.

For full details and free brochures, contact the Sole Australian Distributor, SCAN AUDIO or your nearest ORTOFON specialist.

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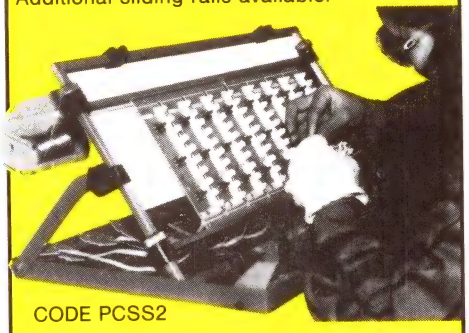

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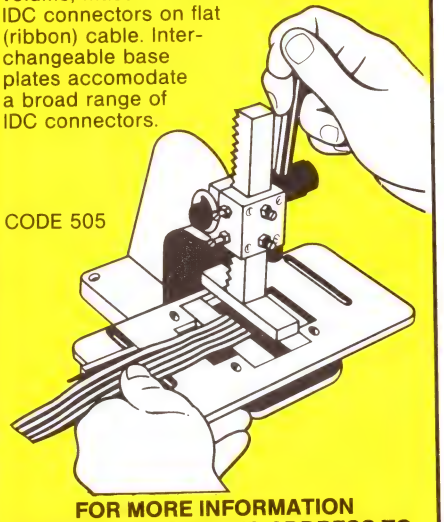

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"Stop-motion" video – set for success?

A look at the unique National M5 video camcorder

Malcolm Goldfinch

When Sony released it's Video 8 mm format a little over three years ago, it seemed reasonable to assume the large format Beta and VHS systems would fall by the wayside when it came to portable home video. But this has not proved to be so. National's M5 VHS camcorder, launched just over 12 months ago, is a full-size machine sporting some unique and advanced features that are only just beginning to excite wide interest among consumers.

IN THE REVIEW of the Las Vegas Chicago Consumer Electronics Show in the March 1987 issue of AEM, I mentioned the 1/1000th-second "shutter speed" for video as a significant announcement. I imagine that many were confused with this term as video does not have a shutter or variable exposure speeds. Unlike the familiar cine camera, video is locked into a time-based format of interleaved, scanned lines and you could be forgiven if you thought the announcement was just another example of the ad-man's hype.

The 1/1000th-second shutter speed is not hype, it is a genuine breakthrough by National and provides unparalleled clarity of high speed action, frame by frame. This is the last bastion of chemical photography to fall to the video assault. As a previous professional photographer, I have been constantly hammered by my colleagues about the twofold weakness of video; poor definition due to the limitations imposed by being locked to a camera equivalent of 1/50th-second exposure time and interlace blurr.

The stop motion video analysis of golf swings or tennis shots are examples of video limitation. For anyone trying to learn from, say, a video of the "Great White Shark", how he flips a buried ball from a bunker into the hole, the head contact point and part of the club shaft will be a blurred mystery. Using the M5 VHS camcorder with 1/1000th-second can overcome problems such as this.

How is it done?

How is a 1/1000th of a second exposure accomplished in video? Simply by starting all over again. This is what National had to do when it researched the Still Video Camera (SVC), an electronic version of your instant camera. National is probably leader in this field, although Canon and Sony would probably dispute this opinion. All have had complete SVC systems in experimental use for some years, complete with modem phone-in imaging that makes them a brilliant catchup for print media competing with TV. Both Konica and Canon now have versions released on the general market, although the retail cost somewhat rules out use by the casual enthusiast.

Now that video cameras have shifted from the traditional vidicon tube to CCD (Charge-Coupled Devices) chips, there is no longer the electron beam with flyback time to consider. The CCD consists of a large number of "receptors" arranged in rows

and columns. In the National M5, there are 579 of these receptors horizontally and 422 vertically. Considering each of these receptors as a bucket, the light focussed on the array by the camera lens excites in each "bucket" a small "charge" according to the colour and intensity of that part of the image which falls on it. Every "bucket's" contents may be measured by transferring its charge very rapidly into a register. The contents of the register can then be read out in a manner rather like the scanning of a TV tube.

In previous CCD systems, the register is read or scanned at the normal TV rate of 50 times a second (for PAL) and then, after some further processing, is sent to the monitor or video tape where the image is stored or displayed. There is no reason why the register could not be scanned at a higher speed than the conventional 50 times a second and it is this fact that has lead to the development of the 1/1000th-second "shutter speed". If the register is read at some multiple of the normal scanning rate, the effect is the same as having a shorter exposure time.

As mentioned above, the CCD in the National M5 has 579 columns by 422 rows of receptors, or a total of 244,338 separate elements. The term used to describe the separate elements is "pixels", simply meaning "picture elements". Those readers who have had anything to do with computer graphics will no doubt be familiar with the term.

Canon has announced a new "Ultimate in High Image Quality" V8 Camcorder, the VM-E2. The half inch CCD has "hundreds of thousands of image sensing elements". I could not obtain a figure, nor could I ascertain if the SVC (Still Video Camera) CCD devices were the same as those used by the same company in their video cameras. Considering the development and masking costs for these chips must cost millions of dollars, I suspect they may be the same.

The pixel count for image chips in still video cameras at the last Photokina was: Nikon and Konica 300K, Minolta uses a Sony 250K chip, Fuji and Canon 380K and National Panasonic with 300K and hopes of a 500K chip shortly!

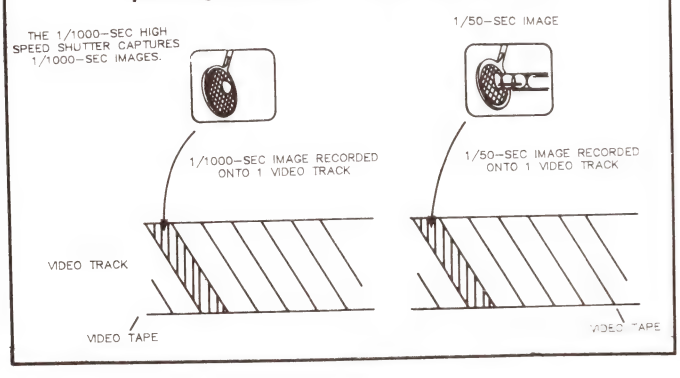
In spite of a study of all press material and the most comprehensive M5 service manuals, I was unable to find any data or philosophy on the exact method used for the 1/1000th-second speed in the M5 camcorder. With the help of Dane Coulton of National, I made a test to prove the theory that the sample from the complete CCD array is made in 1/1000th of a second. I waved my arm up and down as fast as I could in front of a tripod-mounted M5 camera running at standard speed. Whilst doing this, Dane changed the "High Speed Shutter" switch to the "ON" position.

The 1/1000th-second effect cannot be seen at best unless viewed on a VCR with "Super 4-Head System" (S4HS), so the recording was transferred from the M5 to a National NVG-G20EA with "Double Super Fine Slow (DSFS)" playback. On slow frame replay, the theory was dramatically proved.

The first part of the recording showed my swinging arm becoming furry from the elbow out and my hand completely blurred. At the point where the high speed shutter was turned on, the screen went dark, just as expected. As the gain and iris as well as the white balance were automatically restored by the camera, the image re-appeared – with one vital difference. A crisply focussed hand moved up and down in stop motion. Good, clear still photo prints could be made from any of the frames. When this technique arrives in SVC professional cameras, even faster speeds will be possible. The conventional film camera will be left far behind for shooting high speed action because of the greater light sensitivity of the CCD.

When used in high speed shutter mode, the light sensitivity

Operating principle of the high speed shutter.


THE 1/1000-SEC HIGH SPEED SHUTTER CAPTURES 1/1000-SEC IMAGES.
1/50-SEC IMAGE
1/1000-SEC IMAGE RECORDED ONTO 1 VIDEO TRACK
1/50-SEC IMAGE RECORDED ONTO 1 VIDEO TRACK
VIDEO TRACK
VIDEO TAPE
VIDEO TAPE

Picture differences between the 1/50th-sec and 1/1000th-sec "shutter" speeds

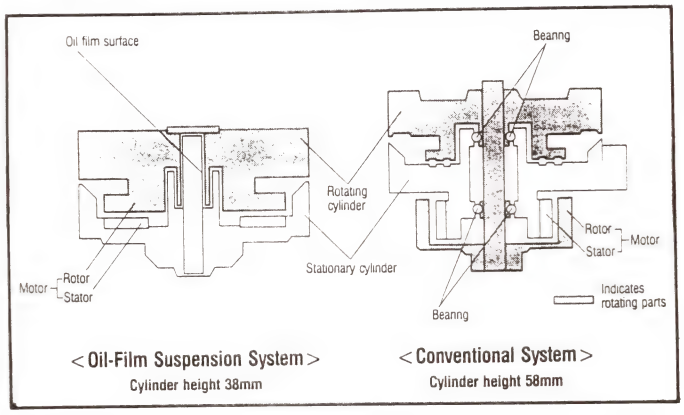
RECORDING METHOD	SHUTTER SPEED	STILL PICTURE	WHEN CAPTURING INSTANTANEOUS SHOTS OF FAST-ACTION SCENES, LIKE A TENNIS BALL BEING STRUCK BY A RACKET
ORDINARY VIDEO RECORDING	1/50 SEC	BLURRED MOTION OBSCURES BALL POSITION	ALL MOVEMENT WITHIN 1/50 OF A SECOND IS CONTAINED ON A SINGLE PICTURE. 1/50 SEC
NV-M5 HIGH SPEED SHUTTER RECORDING	1/1000 SEC	BALL POSITION CLEARLY CAPTURED	ONLY THE MOVEMENT WITHIN 1/1000 OF A SECOND IS CONTAINED IN THE SAME SINGLE PICTURE. 1/1000 SEC

of the M5 is reduced a lot from its normal low of 10 lux. At a guess, 250 lux would be a reasonable figure, but this is a small price to pay for such a perfect still and it should still be well below the light level for a conventional film camera at a similar shutter speed and depth of focus.

Other features

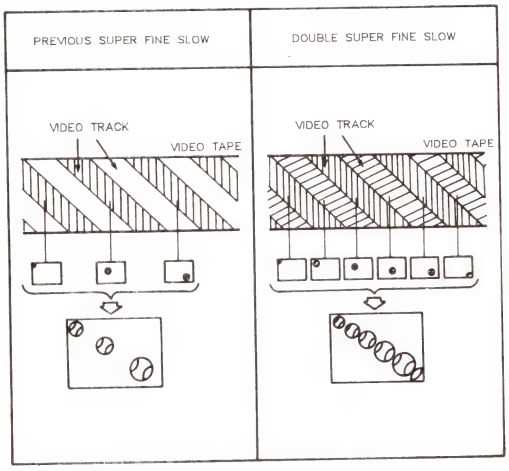
Quite apart from the high speed shutter, the national M5 camcorder has a number of other innovative features which make it a remarkable product.

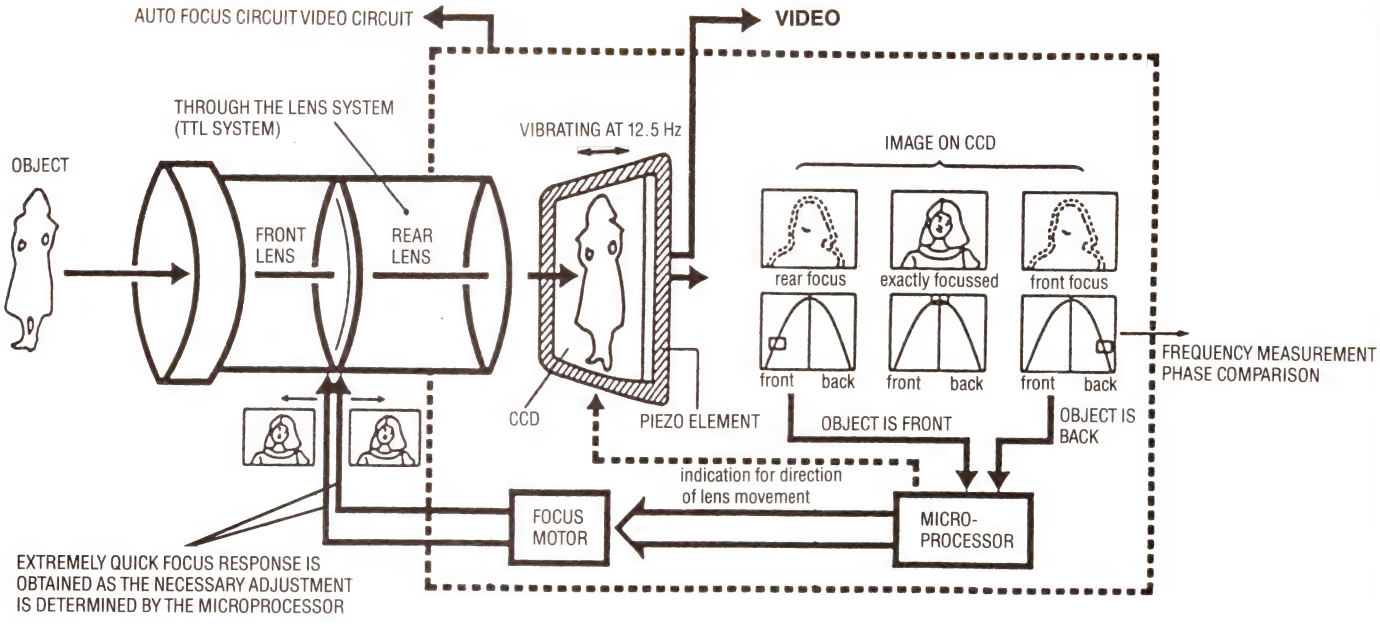
First, consider the "DD Cylinder" motor with oil-film suspen-



sion. Even ball bearings cannot equal floating on liquid film when it comes to smoothness, size and weight. The direct-drive motor in the M5 allows a thinner camera body (from previously 99 mm down to 82 mm). When the cylinder turns, oil flows in specially processed grooves in the thrust plate and shaft, creating the pressure to "float" the cylinder in non-contact rotation. Rotational accuracy remains at 99.999%, according to National.

The "Double Super Fine Slow" feature employs National's newly developed digital servo circuit which allows the Super 4-Head System (S4HS) in their NVG-G20EA to deliver slow ▷





motion reproduction at twice the density of previous slow replay as twice the number of frame tracks are replayed. With the high speed shutter provided by the M5, the slow/still reproduction is remarkable to watch with high speed subjects frozen into clear steps.

Setting the white balance was the bugbear of all early video cameras. Long procedures of pointing at white objects and knob twiddling while the best subject of a lifetime vanished, or an inadvertent rub of a knob making the playback deep blue or magenta are largely removed with auto white balance. National's latest system would appear to be simple and foolproof. The accompanying illustration shows how the complex process is simplified into a sensing block and a gain control/correction block. Primary colour photo-diode sensors detect colour temperature from the subject. These three signals are divided and fed out as R/G and B/G to the gain control which corrects any excess of red and blue, maintaining a constantly balanced level. You may walk with the camera from sunlight to shade, into a fluoro lit room and focus on a tungsten lit subject. The colour remains balanced, no hands, all the way.

Aside from the stop-motion feature, the M5's "piezo auto focus" is an interesting and highly functional facility. Auto focus film cameras of a decade ago were a marvel of their time, although far from reliable and easy to use. Now the average instant camera offers an almost foolproof auto focus system. You must have the subject, or one of them, in the focus field, when you first put pressure on the exposure button. It is easy to fire through between two subjects and have two dear relatives as blurred blobs against a perfectly focussed background. In some cases, glass, patterned surfaces, stripes, wind or light levels can upset auto focus systems using ultrasonic or infrared beams.

National may have come up with the final solution. To avoid the "shoot through" fault, there is a frame in the electronic viewfinder to show where the auto focus is sensing. The field can be altered to wide or small. The sharp edge is found by using a piezo crystal to vibrate the CCD image at 12.5 Hz. As the picture gets better or worse, a microprocessor detects which way the lens must be moved to be in perfect focus. You and I do it this way too, but not quite as quickly. It is almost instant which is a big leap forward. Waiting for the auto focus to decide which way to move the lens can be frustrating in tense shots. The diagram here shows how the scheme works.

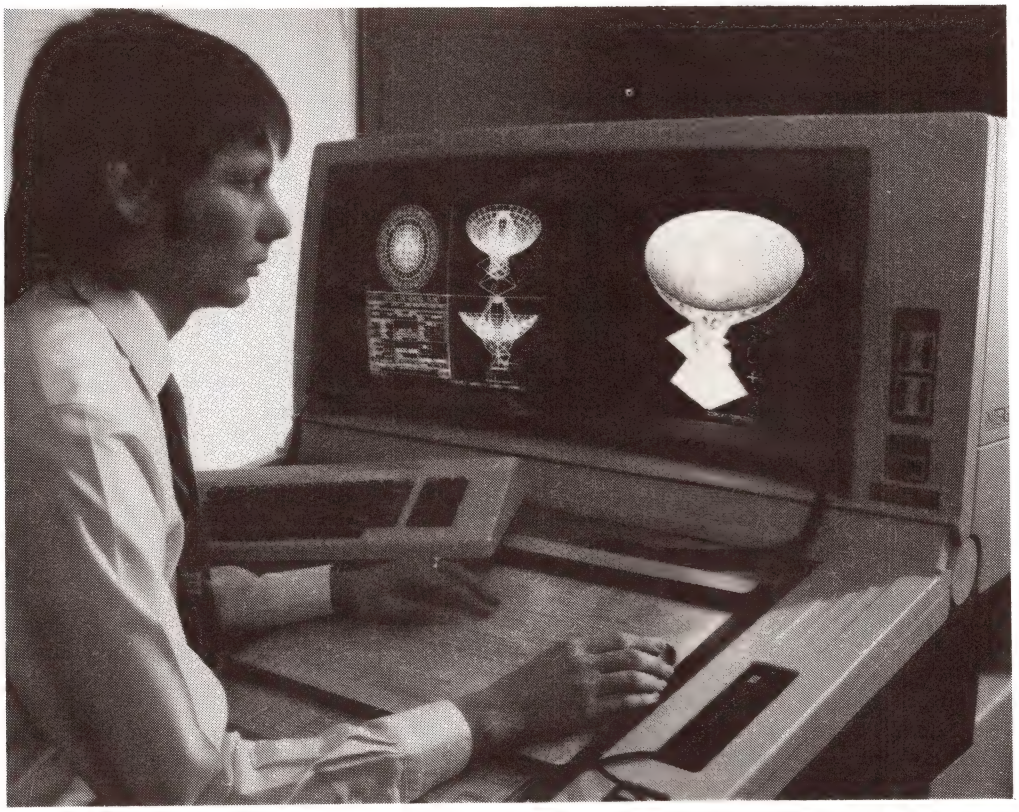
In summary

If you want a small, light, self-powered, universal imaging and playback device, then the M5 camcorder has to be far out in front of anything else. It could be smaller if it used a smaller format cassette, but you would not be able to take tapes from home or a local library and play them on your motel, hotel or friends TV by merely replacing the antenna connection with one from the M5. (National's very recently released MC5 is a VHS-C camcorder with similar features to the M5).

The M5 can also take advantage of new TV receivers which have direct audio and video outputs by recording programmes off air just like a home VCR. The M5 will allow you to dub your own commentary on the soundtrack and an inbuilt clock/calendar allows you to superimpose this data on the image. All other top market features are included such as seconds review of last recording, standby mode to save the battery, cue/review and still modes and remote pause in record. A two hour battery as well as ac and car adaptors are included plus there is a wide range of accessories available.

The M5 represents the most versatile and convenient video device I have yet handled.

CAD role in Australia Telescope design



Both the CSIRO and consulting engineering firm, Macdonald Wagner, used Intergraph computer aided design systems on the Australia Telescope, currently being built at Culgoora, NSW.

The Australia Telescope (AT) consists of seven fully steerable parabolic antennas each with a diameter of 22 metres, together with the well known 64 metre Parkes Radiotelescope. The AT will have a wide spectral range from 300 MHz to 115 GHz and will be the only radio telescope offering such a standard of resolution, sensitivity and diversity in the southern hemisphere for the forseeable future.

Because the accuracy of the dish surface must be better than one tenth of the wavelength of the received signals, deflection and sagging in the structures had to be kept within an absolute range of a few millimetres. More importantly, the relative deflection had to be within a few tenths of a millimetre of a best-fit paraboloid.

The design has turned out to be so successful, a modified form has been used for OTC's new satellite antennas. At the recent Engineering Awards, the Institution of Engineers, Australia gave the design its "Highly Commended" award.

Macdonald Wagner, one of the top five consulting engineering firms in Australia, uses an Intergraph 751, two Intergraph InterAct workstations and four LSI workstations.

The firm bought the equipment in 1982 – being one of the first Intergraph customers in Australia. Once the structural analysis of the design was carried out, the data was transferred to the Intergraph system. The system generated various views of the structure to find the one most useful for the final drawings.

The CSIRO Division of Radiophysics also uses an Intergraph 751 and has Intergraphs InterAct and InterPro workstations. The Division used its CAD system to design certain mechanical details in the structures and to design the four-layer circuit boards for the digital correlator – the "brains" of the AT.

For further information, contact: **Intergraph Corporation Pty Ltd, 55-61 Talavera Road, North Ryde 2113 NSW. (02)888 9900.**

A do-it-yourself "AT"

Well-known distributor of add-ons for IBM PCs and compatibles, Electronic Solutions, has what they claim to be Australia's lowest price IBM AT compatible computer.

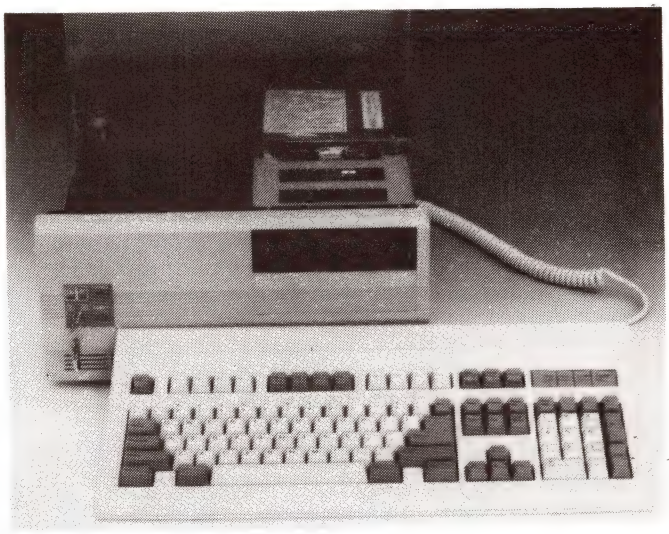
The "Project AT", as it is called, comes in ready to assemble form and offers performance considerably superior to a standard "AT".

The "Project AT" runs at 6/10 MHz with no wait states and comes supplied with 640K RAM on board. A 180 watt power supply, AT style case, Turbo mono graphics card, extended AT style keyboard and both 1.2 megabyte and 360K floppy drives are included.

The normal price for this hardware is $2215.00, but until the 31st January 1988, Electronics Solutions is offering the package for $1895.00 representing a saving of $320.00.

For the faint hearted, the "Project AT" also carries a 14-day money back guarantee.

For further information, contact: **Electronic Solutions Pty Ltd, PO Box 426 Gladesville 2111 NSW. (02)427 4422.**



A mystery solved — how the PBUFF printer buffer project works

Don McKenzie

In the March 1987 issue, we published Don's 256K printer buffer as a Star Project. It has been quite a popular project, which Don markets as a short form kit, and the article proved of interest to a great many readers. However, a number of readers were interested in Don's circuit as no memory decoding or bank switching is used, seemingly "breaking the rules". Don tells how it's done.

SOME TIME after publication of the PBUFF Printer Buffer project, a reader, L. McKeon, wrote to AEM's Editor, Roger Harrison, suggesting that details on precisely how the circuit worked. Several other readers also wrote to the magazine at different times. Roger passed Mr McKeon's letter on to me with the suggestion that I may wish to reply in a format suitable for publication as an article. But before doing that, let me bring you briefly up to date with PBUFF.

I have made a number of changes to the physical design of the project since it was published. The double-sided board is now supplied with plated-through holes. The circuit is virtually the same except for 74LS04 and EPROM pinout. Existing input and output signals, that is, 12 in line at 2.3 inch centres have been retained for compatibility with existing optional add-on boards. These two connectors are now known as J1 and J2. A new connector has been added. This is set out in a 26 pin standard header pattern and is J3. A dual-row male unprotected header can be soldered into this position. A flat ribbon cable is used for board inter-connections. An eight inch length of cable must have a 26 pin female IDC type crimp header crimped onto each end. Boards now simply jumper together with this cable. Provision has been made on the board for an 8K static RAM (6264). However, current versions of software do not use it. This is for future development.

Mr McKeon, from Nundah in Queensland, wrote: "I'd like to see published a 'How it works' piece on Don McKenzie's PBUFF printer buffer from the March (1987) issue of AEM. He uses a 16K ROM and 256K RAM on a bog standard Z80A, but I can't see any components used for memory decoding or bank switching."

A little knowledge

It's surprising what can be done with an elementary micro system and a little bit of knowledge. As an example, let's pose a question for readers well-acquainted with the workings of the Z80 CPU. Apart from a minor aspect, this doesn't have a great deal to do with PBUFF, but it does demonstrate the type of thinking required to manipulate a CPU in a mode not detailed in the manuals:

How many port addresses can be accessed by the Z80?

I would think that 95% of all knowledgeable answers would be 256, since that's the number the reference manuals give. The 256 ports are decoded using the low order address bus (A0-A7) validated with the port select signal (IORQ). This combination gives the chip select signal for any port mapped device. The CPU also issues a read or write signal to inform the port device as to the direction of data flow on the data bus. The port device responds by transmitting or receiving data during the chip select condition.

Let's explore the OUT (C),A instruction. The IN equivalent operates in the same manner. The contents of register C are placed on the bottom half of the address bus (A0 through A7) to select the I/O device at one of 256 possible ports. The contents of Register B are placed on the top half (A8 through A15) of the address bus at this time. Then the byte contained in Register A is placed on the data bus and written into the selected peripheral device. The BC Register pair can be loaded with any value from 0000 Hex to FFFFH. The contents of the BC Register pair appears on the full address bus during the OUT instruction. These sixteen address lines can be hardware decoded to 65,536 discrete I/O ports. The software only needs to set up the BC Register pair prior to the OUT (C),A instruction to select one of these 64K ports. This is 256 times the ports as stated in the manuals. The only restriction with the expanded port configuration is the need for preservation of the standard hardware ports of an existing system.

All port instructions may need revamping. For instance, with the OUT (C),A instruction, the B Register must be set to zero before true (half decoded) ports 0 to FFH are selected. Looking at the IN A,(n) instruction, the contents of the A Register appear on the top half of the address bus. (A8 through A15) This will result in random selection of the 64K ports dependent on the contents of the A Register. These types of instructions will have to be removed and re-written with the dual Register pair types of code. Not very practical for your garden variety computer that probably has BASIC in ROM and can't be changed readily, but if you are building a system from the ground up, and need 346 ports then this bit of knowledge may assist you greatly. If you don't need 346 ports on your computer then erase your memory banks on this thesis for further data.

Copyright

Let me fill you in on what has taken place during PBUFF development. In July 86, I was approached by the Production Manager of Ectron Pty Ltd in Melbourne. They had an existing ▷

For readers interested in the PBUFF project who haven't got the March 1987 issue, back copies (or photostats if copies have run out) are obtainable for $4.00 post paid from AEM Back Issues, PO Box 507, Wahroonga 2076 NSW.

The PBUFF short form kit can be obtained for $39 plus $3.00 postage from Don McKenzie, 29 Ellesmere Crescent, Tullarmarine 3043 Vic. If you need further information on just send Don a stamped (37¢) self-addressed post office preferred size envelope (235 mm by 120 mm) and he will forward information on.

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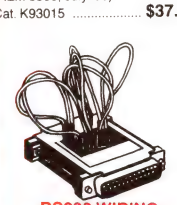

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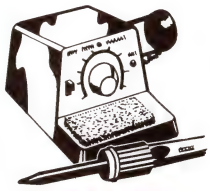

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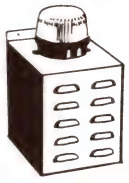

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2 pre-built quality crossovers

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D25T SPEAKER SPECIFICATIONS
Nominal Impedance: 6 ohms
Frequency Range: 2 - 24kHz
Free Air Resonance: 1500Hz
Operating Power: 3.2 watts
Sensitivity (1W at 1m): 90dB
Nominal Power: 90 Watts
Voice Coil Diameter: 25mm
Air Gap Height: 2mm
Voice Coil Resistance: 4.7ohms
Moving Mass: 0.3 grams
Weight: 0.53kg

P21 WOOFER SPECIFICATIONS:
Nominal Impedance: 8 ohms
Frequency Range: 26 - 4,000Hz
Free Air Resonance: 33Hz
Operating Power: 2.5 watts
Sensitivity (1W at 1m): 92dB
Nominal Power: 60 Watts
Voice Coil Diameter: 40mm
Voice Coil Resistance: 5.8ohms
Moving Mass: 20 grams
Thiele/Small Parameters: Qm: 2.4 Qe: 0.41 Qt: 0.35 Vas: 80:1

Weight: 1.65kg

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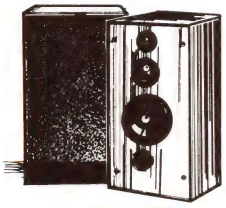

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2 x D75 dome midrange
2 x P25 woofers
2 x pre-built quality crossovers

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D19 DOME TWEETER SPEAKER SPECIFICATIONS
Nominal Impedance: 8 ohms
Frequency Range: 2.5 - 20kHz
Free Air Resonance: 1,700Hz
Sensitivity 1W at 1m: 89dB
Nominal Power: 80 Watts (fo: 5,000Hz, 12dB/oct)
Voice Coil Diameter: 19mm
Voice Coil Resistance: 6.2ohms
Moving Mass: 0.2 grams
Weight: 0.28kg

D75 DOME MIDRANGE SPECIFICATIONS:
Nominal Impedance: 8 ohms
Frequency Range: 350 - 5,000Hz
Free Air Resonance: 300Hz
Sensitivity (1W at 1m): 91dB
Nominal Power: 80 Watts (fo: 500Hz, 12dB/oct)
Voice Coil Diameter: 75mm
Voice Coil Resistance: 7.2ohms
Moving Mass (incl. air): 3.6 grams
Weight: 0.65kg

P25 WOOFER SPECIFICATIONS:
Nominal Impedance: 8 ohms
Frequency Range: 25 - 3,000Hz
Free Air Resonance: 25Hz
Operating Power: 5 watts
Sensitivity (1W at 1m): 89dB
Nominal Power: 60 Watts
Music Power: 100 Watts
Voice Coil Diameter: 40mm
Voice Coil Resistance: 5.7ohms
Moving Mass (incl. air): 44 grams
Thiele/Small Parameters: Qm: 3.15 Qe: 0.46 Qt: 0.40 Vas: 180:1
Weight: 1.95kg

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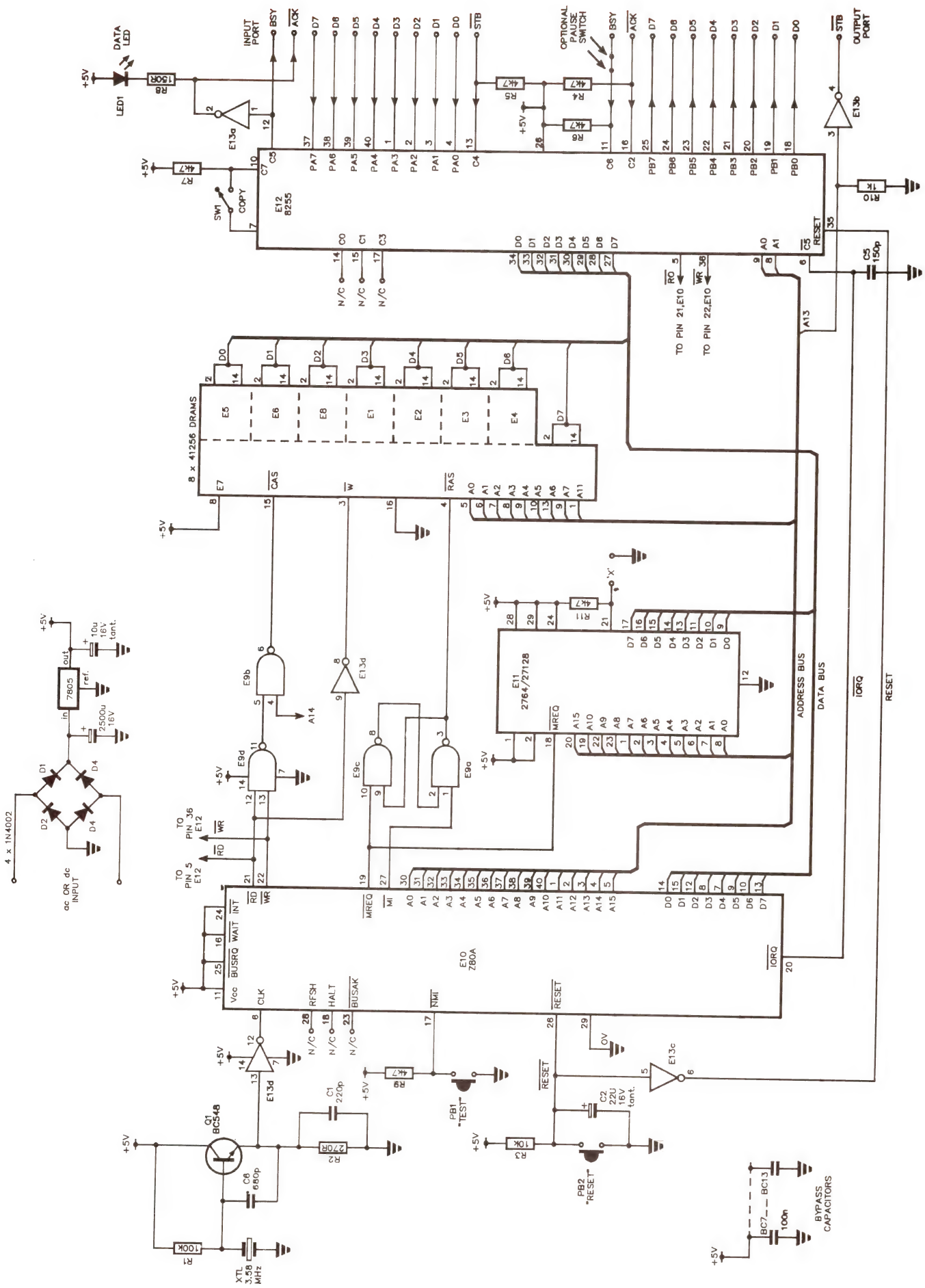

DATA LED
LED1
R8 150R
INPUT PORT
BSY
ACK
D7 D6 D5 D4 D3 D2 D1 D0 STB
OPTIONAL PAUSE SWITCH
R4 4K7
R5 4K7
R6 4K7
+5V
E13a
E13b
OUTPUT PORT
STB
R7 4K7
SW1 COPY
E12 8255
PA7 PA6 PA5 PA4 PA3 PA2 PA1 PA0 C4
C8 C2 PB7 PB6 PB5 PB4 PB3 PB2 PB1 PB0
C0 C1 C3
N/C N/C N/C
RD WR
TO PIN 21,E10
TO PIN 22,E10
A0 A1 C5 RESET
R10 1K
C5 150p
A13
8 x 41256 DRAMS
E5 E6 E8 E1 E2 E3 E4 E7
D0 D1 D2 D3 D4 D5 D6 D7
CAS W RAS
A0 A1 A2 A3 A4 A5 A6 A7 A11
E9b E9d E9c E9a E13d
A14
E11 2764/27128
MREQ
R11 4K7
X'
ADDRESS BUS
DATA BUS
IORQ
RESET
TO PIN 36 E12 WR
TO PIN 5 E12 RD
4 x 1N4002
ac OR dc INPUT
D1 D2 D4 D4
7805 in out ref.
10u 16V tant.
2500u 16V
RD WR MI INT
BUSRQ WAIT
Vcc CLK RFSH HALT BUSAK NMI RESET
E10 Z80A
N/C N/C N/C
0V
E13c
E13d
R9 4K7
PB1 "TEST"
C1 220p
C2 22U 16V tant.
R3 10K
PB2 "RESET"
Q1 BC548
R2 270R
C6 680p
R1 100K
XTL 3.58 MHz
BC7 — BC13 100n
BYPASS CAPACITORS

64K printer buffer, and wished to develop a 256K version. I signed an agreement with them to supply software to enable them to easily convert their 64K buffer into a 256K buffer. I not only supplied my own 256K read/write routines, but integrated them into ECTRON's existing 64K software. The terms and conditions of this contract were met in July 86. This new buffer is known as the "Ectron Model 2256 Data Spooler". As a result of this agreement, ECTRON now have sole and unrestricted copyright on the software that I supplied to them.

One reservation I had regarding this agreement was the fact that I still had a lot more development work that I wished to carry out on the buffer, and I wanted to keep marketing the unit in kit form. Ectron's main interest is in the business market, and mine more aimed at the hobbyist. As agreed to by both parties, the following clause was added to the contract: "Ectron agrees, however, that Don can still continue to supply his original software in EPROM's as part of his Printer Buffer Kit, which is aimed at the computer hobbyist market." The other condition that I imposed on ECTRON was that they could only use my supplied software in a universal type (stand alone) buffer. This leaves me clear to produce a slot or card unit suitable for a specific computer.i.e: IBM PC or Apple type installations. So although I don't hold Copyright on my own 256K read/write routines, I am still able to use them for myself in kit form, and slot (computer specific) form only.

Thus, I am not able to supply to other third party enterprises source code listings or additional software information. I can't let the cat out of the bag. I now have the interests of Ectron to protect. The Ectron buffer is a professional unit in a superb metal case, aimed at the business market, ready to plug in and go, but it costs just a little more than building your own PBUFF. Please note – my PBUFF EPROM will not function in the Ectron spooler. The EPROM is not mapped in the same territory, and the Ectron's front panel controls operate in a vastly different manner.

The situation with software copyright will change slightly with my new software for the Rev.F PBUFF board. This has provision for 8K ROM and 8K static RAM on board. This will enable the user to download a machine language program from a disk file into the buffer and re-program the buffer to suit individual requirements. The read/write routines have been re-written to a new formula. However I will not release source code listings on this information. I do see the need for entry points documented for ROM calls to enable programmers access to PBUFF.

Considering the copyright restrictions, I will now attempt to explain "how it works"

Here's how it's done

The main concept with PBUFF is to dramatically reduce the hardware required to produce a microprocessor controlled printer buffer with a large capacity, and give it a few bells and whistles without additional hardware. No address or data buffers are used or required, providing the CPU is not overloaded. All CPU signals must be electrically as short as possible for reliable operation.

The only port-addressed device is the 8255 PPI (programmable peripheral interface). This is the interface to the computer input and printer output bus. The Z80A's IORQ line is connected to the chip select of the 8255. Any time an I/O instruction is executed the 8255 responds. Any port from zero to 255 is the 8255's port decode. The power-up routines program the 8255 to mode 1, Port A input, Port B output, and Port C handshaking for A and B. Capacitor C5 hanging on the chip select line to ground produces enough of a delay to satisfy the timing restrictions of Z80A to 8255 interfacing.

The printer output strobe is produced by inverting CPU signal A13. One gate of the 74LS04 is used for this. Any time the program sets A13 high, a printer strobe is output. The setting of A13 is actually done with a BC register pair port instruction, not a memory address. This technique of high order address bus port selection has been explained earlier in this article. During a power-up or reset of the CPU, all address and data bus signals go to a high impedance state. The high to A13 appears as a printer output strobe every time the buffer is reset. This is where resistor R10 is useful. Without R10 installed some printers will hang up. They detect the output printer strobe during reset, read the data and issue an acknowledge (ACK) to the buffer. The buffer doesn't pay much attention to this ACK because it has just had a reset and wants to do its initialization routines. Result, the printer goes to sleep. Not all printers, just some, like Star Geminis. With R10 installed, during a reset, instead of A13 tri-stating, it is held low by R10 to ground and this spurious strobe isn't produced.

Pin 12 of the 8255 is the input BUSY to the computer. This signal is inverted by the 74LS04 to produce the ACK signal. This means that while the 8255 is holding the ACK active (low) it sends the BUSY signal to the computer. The ACK is also connected to R8 and the data LED. The LED lights up when the BUSY is high and ACK is low, and switches off when BUSY is low and ACK is high. This LED is used for the ROM diagnostic routines to aid kit builders, and also indicates data entry into the buffer. When the buffer is full, the LED lights up brightly to indicate a full BUSY condition. The value of R10 is a compromise between lighting the LED up brightly enough to see data activity, and not loading the ACK line to the computer excessively.

The reset of the 8255 is a positive-going pulse, which is inverse to that for the CPU. One gate of the 74LS04 is used to generate this pulse from the CPU reset.

EPROM pinout differs slightly between the Rev. A to E boards, and the Rev.F board. The early version uses the A11 pin of the EPROM as a one-of-two software selection method by switching from lower to upper half of the EPROM. The later version uses A12 by either connecting it to the true A12 of the CPU giving a full 8K ROM if needed, or pulling it to +5 volts to select the upper bank.

The EPROMs basically have two chip enables. Ignoring the top four pins in a 28-pin socket and counting the pin numbers as you would in a 2732 package, pin 18 and 20 are the chip selects. Pin 18 connects to the MREQ signal of the CPU. Any memory referenced instruction will select the EPROM, but no data output will take place until you also chip select pin 20. Pin 20 is connected to A15 of the CPU. Any time A15 is low and memory is selected the EPROM is enabled. This gives an effective address for the EPROM from zero to 7FFFH. A13 is already dedicated to the output strobe, so a maximum size of 8K of EPROM can be used. The existing versions of software make use of around 400 hex bytes. I use a larger EPROM than needed only because the larger ones are now more readily available and cheaper.

The dynamic RAMs are enabled when A14 and A15 are high. This gives a starting address of C000H. A15 high disables the EPROM. The addressing and refreshing of 64K Drams in this configuration is not new. Several articles have been written on the subject, even Elektor Electronics U.K. April 86, had an article on this subject. The Z80A takes care of refreshing of the DRAMs in the normal refresh register mode. The data in the refresh counter is sent on the lower portion of the address bus (A0-A6) along with a refresh control signal while the CPU is decoding and executing the fetched instruction. This mode is totally transparent to the programmer and does not slow down the CPU operation. This caters for DRAMs with 7-bit refresh, which to my knowledge covers all 4164s except Texas Instruments types.

The TI DRAMs and all 41256s require an 8-bit refresh. To do this, data bit 7 in the refresh register must be toggled to correspond with the 8-bit format. The program must constantly service this refresh requirement. This involves calling a refresh routine approximately every 256 instructions. This could be done with hardware, but involves a lot more real estate and conflicts with my concept of a simple cheap buffer. ▷

The machine language code to write to a 64K RAM location looks something like this:

```
Assume C register contains the byte to be written.
Assume HL register pair points to the storage memory location.
LD      A,R       ;Get refresh address.
EX      AF,AF'    ;Save refresh.
LD      B,H       ;Save MSB current address for
                  later restore.
LD      A,H       ;Put MSB into A reg.
LD      H,0C0H    ;Select MSB of Dram enable circuit.
LD      R,A       ;Move MSB current address
                  to refresh reg.
LD      (HL),C    ;Write byte.
EX      AF,AF'    ;Restore old refresh address.
LD      H,B       ;Restore MSB current address.
```

The R register does an auto-increment every instruction fetch. To keep track of this register, a save and restore is performed, as every read or write destroys the contents of the R reg. The R register must be preserved for correct DRAM refreshing and bit 7 toggling.

Now what really took place? The LD (HL),C wrote the byte, but where? The byte jumped into the memory matrix that was addressed with the MSB of the address pointed to by the R register, and the LSB pointed to by the L register. The chip select of the DRAMs was enabled by the C0H contents of the H register. You could have loaded the H register with FFH to do the same thing. As long as A15 and A14 are high, DRAM is enabled and ROM is disabled. But if you did load the H register with an FFH, A13 would go high and a strobe would be output to the printer, so settle for a C0H.

So the DRAMs aren't really part of a typical memory map, it's software deception. The true map of the DRAMs as far as the CPU addressing is concerned is C000H to C0FFH. Only 256 addresses. H register set to C0H and L register set to LSB select each byte. The MSB of the DRAMs is dependent on the contents of the R register during a read or write procedure.

Think of the 256 locations pointed to by L register as cells rather than bytes of information, and think of the variable parameter (0-255) that the R register outputs, as a bank select. This gives 256 banks of 256 cells (8 bits wide), a total of 65,536 bytes of data. The cell addresses are at C000H to C0FFH, and the bank select address is loaded into the R register prior to any cell read or write.

What we are left with is a lump of DRAM that is not much good for anything except storing great chunks of data. You can't run a machine language program in it. It's a complete wrap around buffer. When the storage pointer gets to FFFFH, its next location is zero, and round'n'round it goes.

To access the full 64K of these types of dynamic RAM, The input address lines are multiplexed. The bank select is equivalent to a row address strobe, (RAS⋆) and the cell select is the column address strobe (CAS⋆). RAS⋆ and CAS⋆ timing is generated using the 74LS00 as follows (the ⋆ following a signal name means it is active low):

RAS⋆ generation: CPU signals M1⋆ and MREQ⋆ are low during every CPU instruction fetch cycle. This keeps the output of the flip flop (E9 gate a,and E9 gate c) and thus RAS⋆, high. After this fetch cycle, the contents of the R register are placed on A0-A7, and the CPU starts an execution cycle with MREQ⋆ going high, followed by M1⋆. Only when MREQ⋆ goes low again will the flip flop toggle to activate the RAS⋆ lines, which will remain low until the next CPU fetch cycle.

CAS⋆ generation: This signal will be active during every CPU read or write cycle with A14 high (Dram enable) and A15 high. (EPROM disable) The WR⋆ line is generated from the RD⋆ signal using one gate of the 74LS04.

8K to 64KRAM operation: With the 8K to 64K version of software (V2.2), a single 4164 can be used for an 8K buffer. The power up routines check memory size, and select the appropriate read/write drivers. An 8K buffer for instance will get a byte from your computer, and place it in bank 0, cells 0 to 7, as a single chip is only one bit wide (65,536 by 1). When retrieving this byte, it must gather up information from cells 0 to 7. A 64K buffer writes the full eight bits (one byte) at a time. Bank 0 is selected and cell 0, then cell 1, up to cell 255. When the first cell array is full, bank 1 is selected, and so on. The software checks for buffer full condition so that no overflow onto existing data can occur.

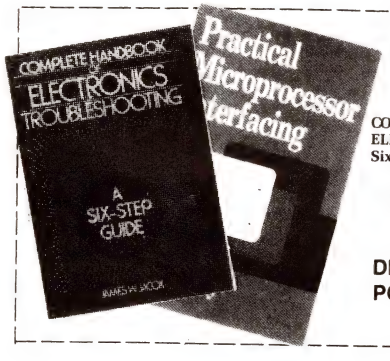
256KRAM operation: The full eight DRAMs (41256) must be installed for Version 3.2 PBUFF. We now introduce a page selection mode. Pin 1 of the CPU is connected to pin 1 of the Drams. This is CPU A11, and the additional address pin of the DRAMs. I could have used any CPU address line that wasn't dedicated for device decoding, but pin 1 to pin 1 has an unbelievable ring to it. This decodes the cells into CPU addresses C000H to C0FFH, and C800H to C8FFH. Every address pin you add to this type of DRAM expands it's total memory capacity by four times. The software sets up pages 0, 1, 2, and 3. The first byte written is to page 0, bank 0, cell 0, then to P1, B0, C0. The full 4 pages are filled before the next cell is selected. Cell addresses at C000H are used to select pages 0 and 2, and cell addresses at C800H for pages 1 and 3. Discrete page selection between 0-2, and 1-3 is done with internal software. This gives the four states for MSB, and LSB page selection. And this is where I must fall short of the complete account of the 256K technique due to the copyright laws covering this ground as outlined earlier in this article.

CPU signals

Only a small explanation on a few CPU signals is all that remains. The crystal, Q1, R1, R2, C1, C6, and one gate of the 74LS04 are used to generate a reliable clock usable by the Z80A. The Z80's like as near as possible to a 0 to +5 volt swing. My original circuit had a couple of gates of a 74LS04, a few resistors and capacitors, and the crystal. It worked OK until an SGS brand 74LS04 was used. Altering the value of the resistors in the circuit overcame this problem, but I felt a more stable clock circuit was the order of the day.

The Test (NMI⋆) and reset pins of the CPU are held high via R9 and R3. Pressing the switches grounds these points and the program counter is set to a new value. The reset jumps to address zero, (same as power-up), and the Test jumps to 66Hex, which outputs the test message. Capacitor C2 is used to debounce the reset circuit.

As the method of accessing the DRAMs rules out running any software in this region, the only bytes that can be used for programming are the 208 bits of the CPU registers. The stack pointer is only used for arithmetic functions, not in the normal mode, so CALLs or RETurns can't be done in the usual fashion. I don't have the luxury of using a full byte as a flag. One bit generally accounts for a flag. The software has been expanded about as far as it can go without additional hardware. As mentioned before, the Rev.F board has provision for an 8K static RAM. This will open up new uses for PBUFF, and add many new features.



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Build a "supermicro"

Roy Hill

Over the past year, several manufacturers have released a crop of super-powerful microprocessor chips having previously undreamed-of speed, power and flexibility. In the forefront is the Novix "Forth engine" series which not only provide computing speed rivalling many current mainframe and mini systems, but the power of being able to be programmed directly in a high level language. This project, designed and presented in conjunction with our old friends Chris and Dan Darling of Maestro Distributors, describes a "supermicro" which, literally, puts the power of something like a DEC VAX 11/780 minicomputer (or better!) in your hand.

WELCOME TO THE FIRST of a multi-part introduction to the Novix NC4016 16-bit "superprocessor" and the kit that Maestro has developed to unleash the awesome power of this chip. Firstly, allow me to provide a synopsis of the project and its proposed development over the next few months in this magazine.

This project is, without a doubt, the most ambitious ever tackled by AEM and, indeed, it is probably the most ambitious kit project ever presented to the enthusiast. In this article I will present an overview of the project and details of how to obtain the kit. In the second part (next month), I will provide construction and assembly details. In the third part, troubleshooting and diagnosis details will be covered and in subsequent issues I will provide software and programming examples, additional expansion features and user-supplied hints, tips and programs. Of course, the latter will depend on user feedback and if our last major project (the AEM4610 Supermodem) is any indication, there will be no problems in this area.

The Novix NC4016 superprocessor

Potential constructors of the kit are invited to check out the October and November (1987) issues of this magazine for a brief introduction to the Novix NC4000 series of microprocessors (see the Semiconductor Scene column). The Maestro kit is built around the NC4016, which is the junior member of the family. This is a full 16-bit chip, but this in itself is rather a misleading term as conventional semiconductor concepts and terminology really don't apply to this chip and its siblings.

The NC4016 chip was designed by Charles Moore (who invented Forth) and it is dedicated to running Forth as its external microcode. Allow me to elaborate on this concept a little. In a conventional microprocessor, we write a program (let's say in "C", for example). When the program is compiled (after de-bugging, of course), it is translated into machine language. This is the set of familiar hexadecimal op-codes (operational codes) which are produced by an assembler. These op-codes (for example – MOV AX,0) are then decoded by the internal microcode of the processor into a series of commands that channel data through various combinations of gates and clocked logic circuits that form the ALU (Arithmetic and Logic Unit).

This, of course, is a rather oversimplified account of the process, but it is sufficiently accurate for our purposes. This serial translation process is not without some heavy penalties. The first part of the process (the compiler), produces far more object code (hex op-codes) than does the corresponding program written in pure assembly language. This is due to the fact that compilers are usually written more for accuracy of compilation (how closely the object program does what the programmer wanted), rather than for high efficiency. Secondly, the conversion of the hex op-codes to microcode imposes the additional penalty of propagation delays (that is, they take time to pass on the pulses of 1s and 0s) as the data/instructions are decoded by the gates inside the ALU. The answer to these problems to date has been to crank up the throughput by trying to:

(a) Optimise compilers for greater efficiency of code generation.

(b) Increase the clock speed at which the chips run.

(c) Increase the size of the data bus (the number of bits the computer can handle at one time).

All of these "answers" to the problem introduce new problems of their own (more power consumption, higher operating temperatures etc) and so often defeat the very thing they were attempting to overcome.

Enter the Novix. This processor was designed to remove the microcode both off the processor and out of existence. One problem (bottleneck!!) gone. Forth is the high level language and the Novix uses Forth as its "external microcode." Here we have a processor which the programmer talks to directly. The Forth *words* we write are interpreted/compiled directly into instructions to gates, without the need for microcode. The other problem is that Forth itself is considered to be a high level language (NO CORRESPONDENCE WILL BE ENTERED INTO ON THIS TOPIC) and it is fairly easy to learn to program in Forth (much easier than to learn assembler, I can assure you!).

The Novix has been optimised to run Forth. There is no other processor/co-processor pair on the market that can touch this chip for sheer, raw computing power. Forget those snail-like 80386/80387 processors. They can't hold a candle to the Novix (except in terms of the heat they generate – a friend of mine uses an 80286/80287 to heat his greenhouse. No, they don't control the heater, they ARE the heater!). The Novix runs so cool, you'd swear it was dead. No dissipation problems, no heatsink required. Aside from the fact that one has to learn Forth to use this chip effectively (and I don't consider that a disadvantage), I really can't think of any drawbacks to the Novix. An absolute delight to own. ▷

The Novix board

This board has been designed to blitz ANY OTHER MOTHERBOARD OR TURBO/SPEED-UP BOARD ON THE MARKET. With the help of the Novix superprocessor, that wasn't hard, but stop to consider – here is your chance to own a computer that runs as fast as many mainframes (they had to slow our Novix down to allow a VAX 11/780 to keep up) and costs only $700.

The project has been built on an IBM standard card, so that all those users with an IBM or compatible can plug it straight into one of their 16-bit slots. (If you haven't got and IBM/compat – keep reading!) Note that it will not fit the AT's 32-bit slots, but will fit one of the three 16-bit slots on the AT. It will also fit inside the clones. However, be warned – even if you have an AT clone running at 12 MHz, the Novix board will spend nearly all of its time "twiddling its thumbs" whilst waiting for the clone to give it something to do.

The "standard" board (see Figure 1) is provided with a 15 MHz crystal, which gives an operating speed of about 5 MIPS (million instructions per second). At this speed, the Novix is in low gear, with top revving out at 12 MIPS. Notice how easily I said that – 12 MIPS. Now let us pause for one second to take that in. At top speed (12 MIPS), the Novix is capable of outrunning a VAX 11/780 by a factor of about four to one. I am still having a little trouble coming to terms with the true meaning of these figures. As a matter of record, the top speed that this board will run at is about 8 MIPS. The reason that it won't run any faster is not from any design limitation, but simply economics. High speed RAMs are simply too expensive to justify.

For those of you who don't have an IBM, the board will communicate with any computer that has a standard RS232 interface. The project has a serial connection on board and uses Tx, Rx and GND as its only connections to a host serial port. Anyone who feels inclined can do the calculations, but I can assure you that there is no microcomputer serial interface card that will run fast enough to stop the Novix from "twiddling its thumbs" for more than a few microseconds. The host computer, of course, may very well be gasping at this stage.

The Novix, when used in this "external serial" mode will be able to make use of all of the host computers peripherals (e.g: floppy and hard discs, monitor, printer etc.), so that Novix source code screens may be saved, dumped etc. For those people without *ANY* form of computer, the project may be used in a total "stand alone" mode. The serial port then becomes the interface to a serial terminal (something capable of driving a monitor), or, alternatively, the project can drive its own monitor.

The reason for mentioning serial terminals is fairly simple – a large number of people have serial terminals lying around. (Even an old Microbee may be pressed into service as a serial terminal). I have two serial terminals and one of my first projects has been to get the Novix board up and running with one of them. Storing modified source screens is as easy as in the previous two methods, but still relatively simple.

When the Novix first fires up, the Forth Kernel and source screens are downloaded from (relatively) slow EPROM to fast RAM. This then enables the user to modify the source screens to cater for individual applications. The original EPROMs may then be replaced with blank ones and programmed using the on-board EPROM programmer. Oh, sorry about that. I should have warned you. This little board is crammed full of goodies.

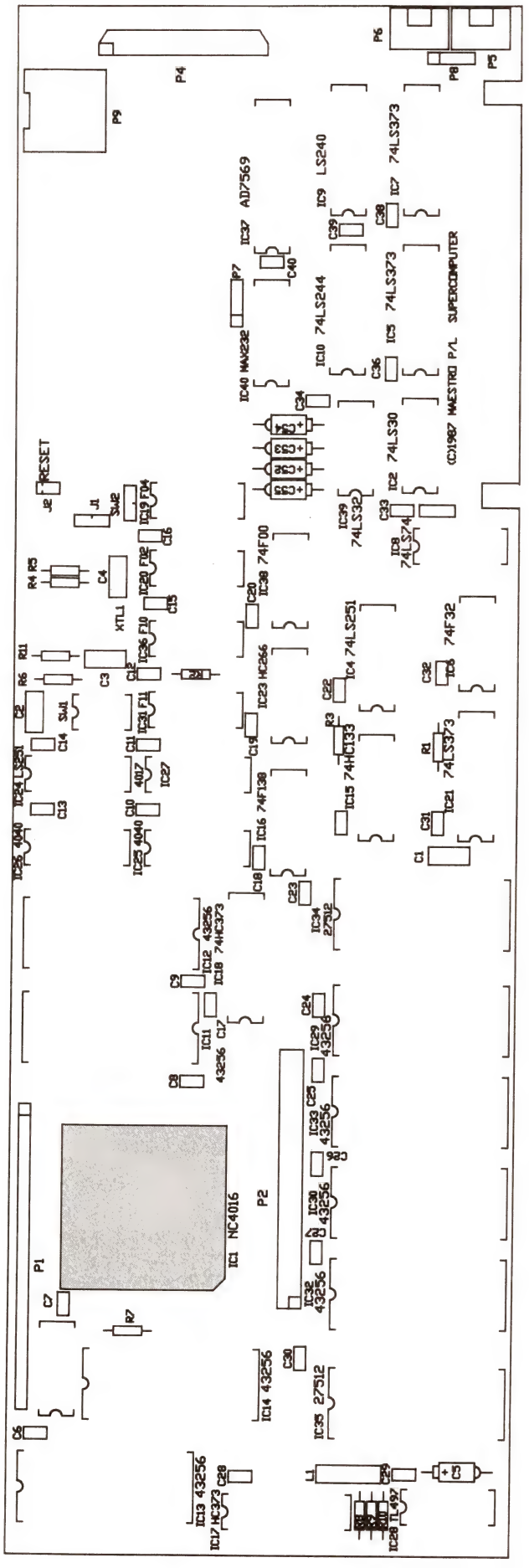
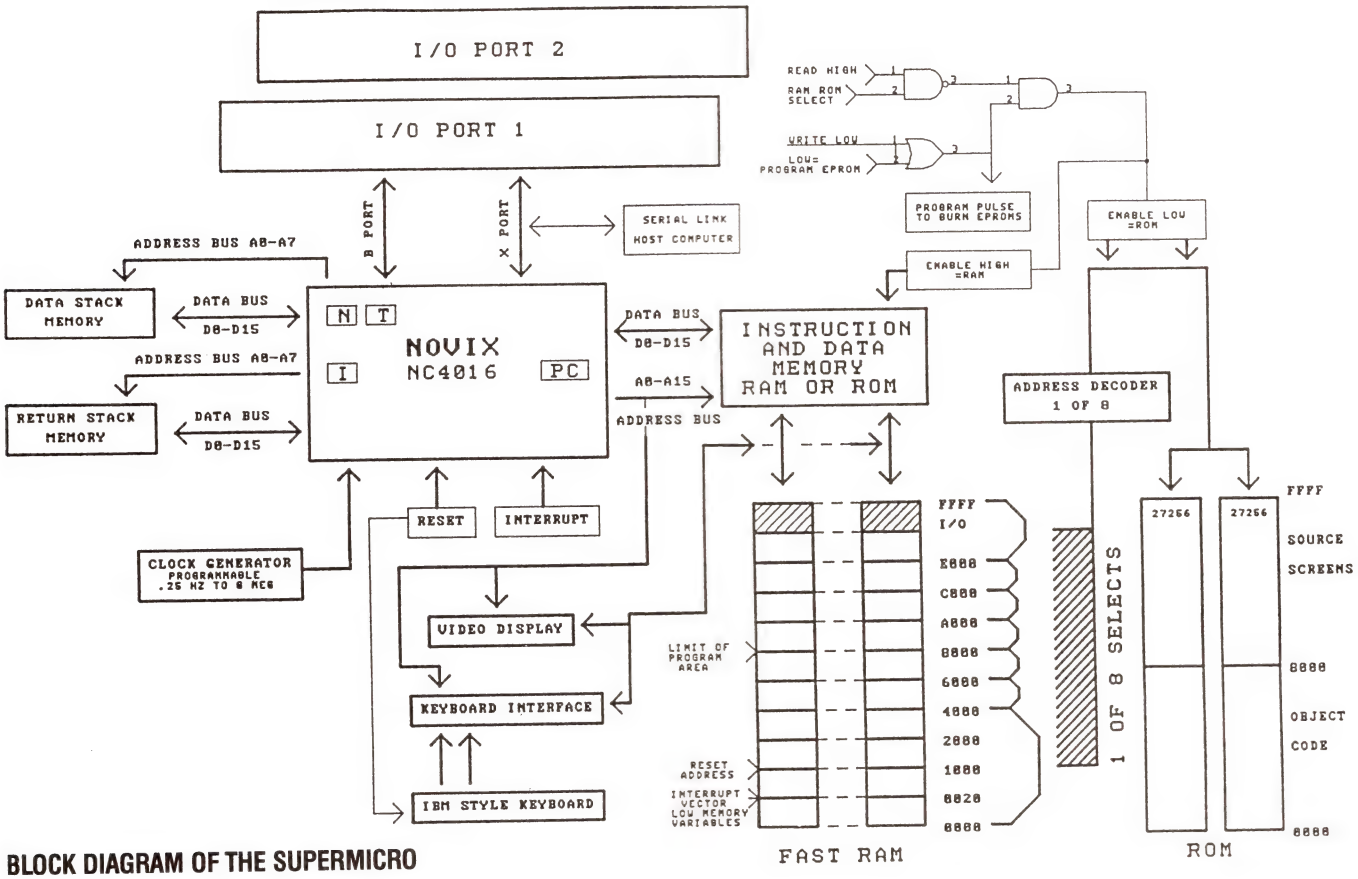


Figure 1. The supermicro is built on an IBM standard card. It may be used in an IBM or compatible, or stand-alone via its on-board serial port.



BLOCK DIAGRAM OF THE SUPERMICRO

Details of the board

Let us examine Figure 1 in detail. Although the board and the corresponding circuit diagram look fairly complicated, the logic is fairly easy to follow. In the top middle-left of the board is IC1, the 64-pin PGA (Pin Grid Array) of the Novix NC4016. In order to prevent damage to this chip and remove the worry of a potential constructor destroying $300 worth of semiconductor in a flash of agony, the board is supplied with the *fully tested* NC4016 already installed in a LIF (Low Insertion Force) socket. UNDER NO CIRCUMSTANCES SHOULD THIS CHIP BE REMOVED FROM ITS SOCKET (unless, of course, you're flush with cash). The chip is a CMOS gate array and all the normal CMOS handling precautions are necessary when constructing this project.

To the left of this chip are ICs 13 and 14. These are 43256 SRAM chips (256 kbits x 8) and are used for the LOW and HIGH bytes of the Data Stack, respectively. Immediately to the right of IC1 are ICs 11 and 12. These are the twins of the Data Stack, being the LOW and HIGH bytes of the Return Stack, respectively. Immediately below the NC4016 are the system ROM and RAM chips. ICs 34 and 35 are the ROM chips – 27512 EPROMs (512 kbits x 8) and represent the LOW and HIGH bytes respectively. ICs 29 and 33 and ICs 30 and 32 are 43256 SRAMs (256 kbits x 8) and represent the LOW and HIGH bytes, respectively. From this, it is fairly obvious that there is a one-to-one correspondence between the EPROM address space and the RAM address space. At the very bottom left of the board, the components labelled L1, C5 and IC28 are those responsible for the generation of the 25 volt EPROM programming voltage. IC17 (immediately above them) and IC18 (below the Return Stack chips are the decoding chips for the Data and Return Stacks, respectively. The crystal is a 15 MHz HC18 can type, and is located on the top right-hand of the board. The system clock is derived from the this crystal and parts of ICs 20 and 28. ICs 25 and 26 form the divider chain. IC24 is used to multiplex these clock signals.

IC37, in the right-hand end of the board, is the AD7569-8 bit A/D converter, which will be discussed in detail later. Details on this chip can be found in the Semiconductor Scene column of this magazine (November, 1987, pp 29 & 30). Immediately to its left is IC40, which is a MAX232 single voltage supply RS232 logic generator chip. This chip has been fully described in a previous issue (August, 1987, pp 78-80) of this magazine.

The 4-pin DIP switch in the top centre of the board (just below and to the left of the crystal) is used to select the Mark/Space ratio used. This is determined by the speed of RAM that is selected by the user.

P1 and P2 (the two connectors at the left-hand end of the board) are used to drive expansion boards at a later date. P4 (the DB25S connector at the far right-hand end) is used for an external A/D converter interface.

I'll keep you in suspense for a little longer on the rest of them, though. Once the modified screens have been compiled and added to the dictionary, the new *words* that were generated may also be burned into the EPROMs. One can, in fact, use the Novix board as a serial EPROM programmer, as well as modifying multiple or single screens, individual words, or even single bytes. More on this later.

The on-board RAM is the main factor in determining the ultimate performance of the board. Standard 120 ns static RAMS (called SRAMs) will enable the Maestro board to run at about 4 to 5 MIPS. How this is done will be explained in the next issue. More expensive 100 ns SRAMs will allow it to operate at about

– to page 77. ▷

A glossary of data comms jargon

I THOUGHT it would be a good idea to start off the new year with a glossary of the terms used in the data comms arena. I have not included all the terms used, but have only attempted to cover the most common ones.

ADPCM: Adaptive Differential Pulse Code Modulation (see also PCM) – a means of improving the signal-to-noise ratio of the DPCM transmission, by altering the sampling ratio.

ASCII: American Standard Code for Information Interchange – a data code used by all the world, except IBM mainframes.

BAUD: The term usually confused with bps (bits per second). Baud rate is a measure of the number of discrete transitions made on the line in one second. Thus 1 baud can mean 1, 2 or 4 bps, depending on the encoding method used.

BCD: Binary Coded Decimal – the means by which numbers are represented as binary digits. It works by directly translating each decimal digit in the number to its 4-bit binary equivalent.

BDLC: Burroughs Data Link Control – A variant of the HDLC and SDLC controls. (These two acronyms are explained later).

BELL: The famous (or infamous) "Ma Bell" of the USA. Responsible for the definition of the original modem speed standards (which no-one outside the US uses).

BPS: Bits Per Second – a measure of the number of zeroes (0s) and ones (1s) being transmitted.

CCITT: The "Comite Consultatif Internationale pour Telegraphique et Telephonique" - a chance to practice your French. This august body of savants spends most of its time dreaming up ways to make the lives of simple people like us far more complicated than is necessary (i.e: they set communications standards and practices).

CRC: Cyclic Redundancy Check – a means of trapping errors that occur during data transmission over a modem line. Does not have any error correcting capabilities, however.

CTS: Clear To Send – an RS232 signal that is asserted by a DCE device, or a DTE device indicating that it is ready for the next piece of data (see also RTS).

DCD: Data Carrier Detect – once again a DCE device signal (usually a modem) that is used to indicate that a correct carrier signal (from another modem) has been detected.

DCE: Data Communications Equipment – A device connected to a computer that is used to process data provided by the computer. It may be either a modem, a printer, a paper tape punch or other similar device.

DLC: Data Link Control – another name for this is "line protocol" – used over networks as an error checking and correcting mechanism. Sliding window, CRC, polling, VRC etc., are all DLC error correction controls.

DPCM: Differential Pulse Code Modulation (see also PCM) – Uses the 256-bit quantizing level to determine the initial value to be transmitted and then transmits the DIFFERENCE between this value and the next one as its signal.

DSR: Data Set Ready – again, a DCE device signal, indicating that the device is on-line and ready for action.

DTE: Data Terminal Equipment – used to mean a terminal (no storage or computing capability), must is more frequently used to refer to a host computer.

DTR: Data Terminal Ready – a corresponding (i.e: handshake) signal from a DTE device, indicating that it is on-line.

EBCDIC: Extended Binary Coded Decimal Interchange Code – A data code used by IBM to show that they don't need to use the one that the rest of the world uses (ASCII).

EOT: End of Transmission – A signal from a DTE device indicating that the transmission is complete.

FDM: Frequency Division Multiplexing – transmission of binary data by splitting a frequency band into smaller bands (called subchannels) – only useful for relatively low speed transmissions.

FM: Frequency Modulation – use of a variable frequency (rather than amplitude) to transmit analogue data (e.g: radio transmission).

FSK: Frequency Shift Keying – another means of converting digital to analogue for transmission or storage. Instead of using two different amplitudes (as in AM) to represent binary values, two different frequencies are used.

HDLC: High Level Data Link Control (see DLC)

ISDN: Stands for Integrated Services Digital Network – a way of sending modem manufacturers out of business, as there will be no need for a modem when ISDN is up and running. Judging by the all-round confusion (from manufacturers to Telecom authorities – not OUR Telecom, they know EVERYTHING), the translation may be better put as "I Still Don't kNow."

LAN: Local Area Network – a means of interconnecting a miscellany of PCs, minis and mainframes in a typical office.

LLC: Logical Link Control (IEEE 802.2) – a subset of the HDLC specification.

MAP: Not a means for finding your way round, but Manufacturing Automation Protocol (developed by General Motors (not IBM?)). Used to standardise the data comms used in fac-

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tory machines for the automated manufacture of consumer items.

MFM: Modified Frequency Modulation – used to store data in digital format on magnetic media, usually floppies and hard discs.

OSI: Open Systems Interconnection (also known as Obviously Still Inconsistent). A means for connecting one computer to any other (except IBM), by means of a cable connected to a LAN.

PCM: Pulse Code Modulation – A means of converting digital data to analogue data, usually for either transmission (modem, wireless etc.) or for storage (usually magnetic media). The signal amplitude is divided into 256 even "slices" called quantizing levels.

PSTN: Public Switched Telephone Network – the telephone system that we use in our everyday life.

QAM: Quadrature Amplitude Modulation – A means of encoding more than one bit into a single event or transition in the transmission of binary data e.g: V.22bis and V.26ter.

RTS: Request To Send – A request from a DTE device or a DCE device to get the next character (see also CTS).

SDLC: Synchronous Data Link Control – IBM's version of an HDLC, which makes use of the "Go-back-n" method of error correction.

SNA: Systems Network Architecture – IBM's version of OSI (qv), designed to stop other people connecting to IBM machines in any intelligent manner. Besides, IBM is the only manufacturer of computers, isn't it?

TDM: Time Division Multiplexing – splits the transmission band into time slots so that each terminal on the network receives an equal portion of time.

TOP: Technical and Office Products system – developed by Boeing (one can only wonder where IBM were again). Similar to MAP in its application.

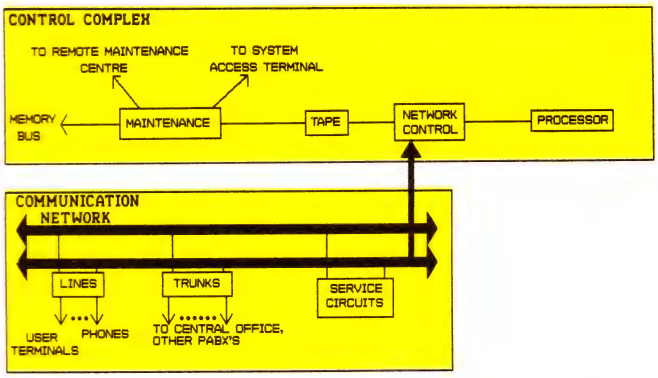
WAN: A Wide Area Network – a means of interconnecting a miscellany of PCs, minis and mainframes located in offices over the area of a city. Wide Area Network Kits are available for many computer manufacturers.

Telecom strikes again!

Telecom (not my favourite public utility, as many of you are well aware) has done it again. Charges for its modem registration fees have risen again, by a minimum of at least $100. That's not too bad I suppose, but they've also introduced an annual registration fee of $150. Boy! Consider the average modem kit builder. Firstly, the cost of the kit, say $400. Then the approval fee, now $700. Then the annual registration fee, $150. Then the phone bill, usually $300 p.a. rental plus, say, $250 for calls. Total – $1800 – and that's only for the first year. At least most of my costs are tax deductible.

Now there's another good idea. Telecom should take over the Taxation Department. With their philosophy, our annual budget would able to show billion dollar surplusses. Whilst I am quick to criticise our friendly phone provider, I am also well aware that we could be far worse off. Experiments in privatisation in several countries (Britain and the U.S.) have not been totally successful, with the standard of service very often deteriorating after the utilities have gone to companies. It's hard to imagine how our service could be any worse than it is now, but I suppose we could always try to find a way to plumb new depths.

Whilst on the topic of Telecom, I have noticed a fairly big push in the States for the All-Digital PABX. A typical example of this is A.T. & T's Model 75 (shown in the diagram reproduced here). Naturally, the digital PABX is capable of handling both voice and data switching, so it is providing the capability of handling ISDN when it enters the marketplace. The only uncertainty about the future of these all digital PABX's is whether they can successfully compete with LANs and other networking facilities in an office environment.



That's all for this month. Next month starts the project for which you've all been waiting. The Novix board designed by Maestro is available and a complete description of the board, construction and use commences in next month's issue. However, this also means that a temporary suspension of Dial Up is necessary. The Dial Up column should recommence around mid-year, so keep your eyes open for its return at that time.

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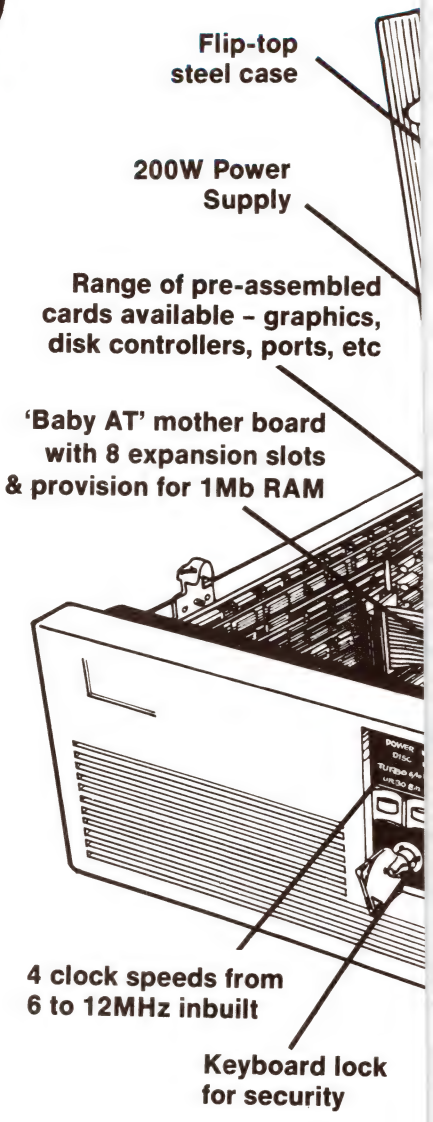
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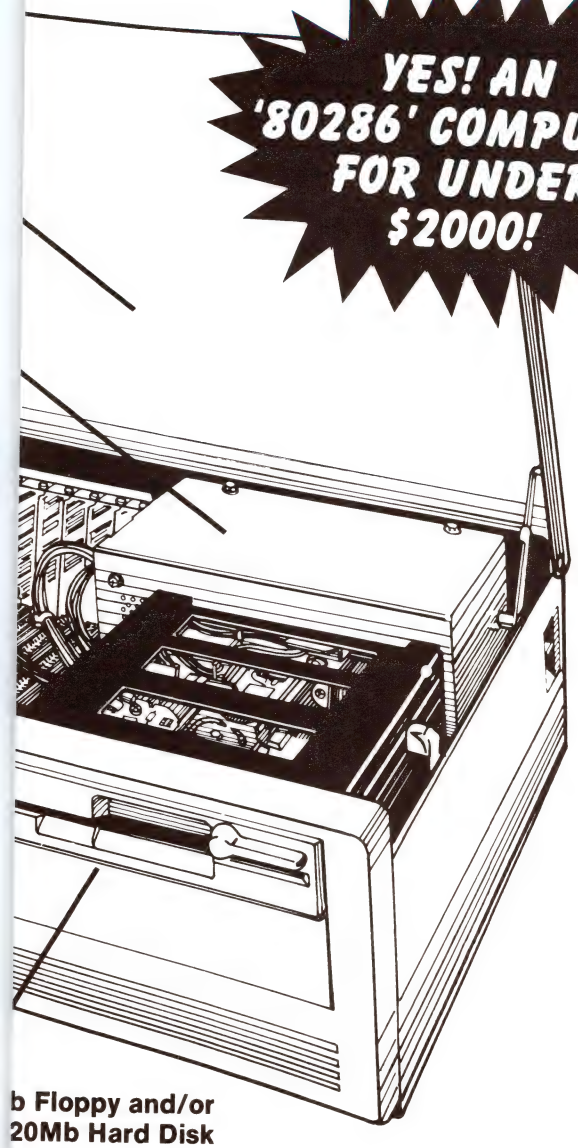

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Icom's modular multi-band mobile

The new IC-900A series transceiver system from Icom is an entirely new concept in amateur band communications systems, they claim. Using a modular design and employing optical fibre links, users can mix and match band modules between 28 MHz and 1.2 GHz to suit their requirements.

The IC-900A remote control module incorporates all the normal front panel features and measures just 150 mm wide, 50 mm high and a tiny 25 mm deep. Weighing only 200 grams, the module is easily fitted to modern automobile dashboards.

The Interface Unit-A caters for all external connections such as speaker and microphone and uses optical fibre for the link to the second Interface Unit-B. The Interface Unit-B module contains the common power, preamplification, frequency, data and control circuitry for the individual band modules.

Up to six individual band modules can be located with the Interface Unit-B, all securely mounted where they can't be easily removed or stolen such as under seats or in the luggage compartment. Each band module is parallel linked to the Interface Unit-B and contains its own frequency selection circuitry, memory section, power amplifier and antenna connector.

As each of the band modules is optional, you only need to pay for the bands required. With all five optional band modules, the IC-900A provides full-featured FM operation on all amateur bands from 28 MHz to 1.2 GHz with a total of 50 memories. Full duplex operation is possible and the dual frequency display module shows the status of any two band modules simultaneously.

For further details on this innovative transceiver system, contact your nearest Icom dealer.

Albury-Wodonga exhibition

The Twin Cities Radio Club of Albury-Wodonga will be establishing a display depicting the history and development of radio and electronics in Australia. The display will be in conjunction with the national travelling exhibition which will start from Wodonga.

There will be an awards station on both HF and VHF from January 1st to January 31st. A certificate will be offered to stations making one contact with the special event station or any club member station. A special event callsign has been requested but no details were to hand at the time we went to press.

Amateurs from around Australia are invited to the border tourist area to see the huge displays and live enactments.

The club is seeking old gear for display and posters etc would be most welcome, either as donations or on a loan basis.

For further details, contact the **Twin Cities Radio Club at PO Box 396, Albury 2640, NSW or via FAX on (060)561 030.**

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For many years, RF engineers have been hamstrung by the lack of good quality capacitors that are readily available in this country. As part of their continuing support for RF component users, Stewart Electronics of Victoria announce the release of their selected range of High-Q VHF/UHF multilayer chip capacitors as a solution to the problem.

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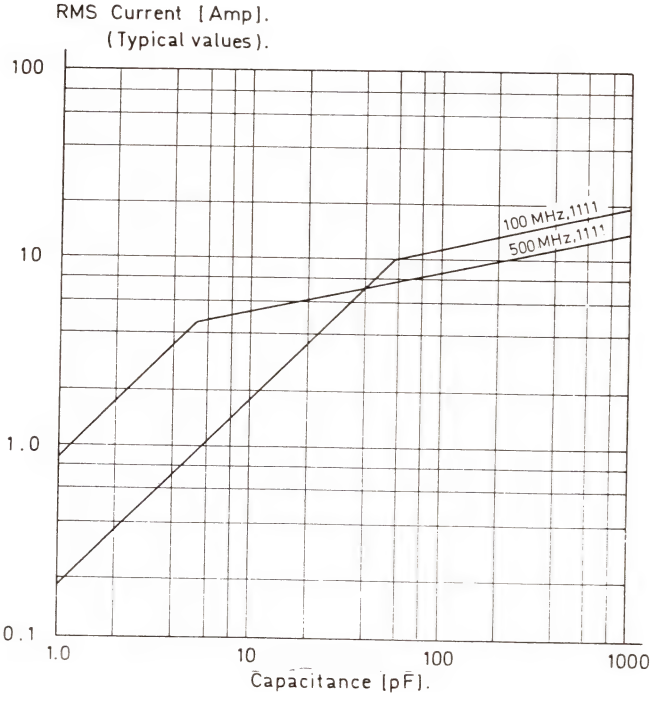
The multilayer capacitors from Stewart are manufactured by Ferroperm of Sweden and are characterised with graphs of ac current ratings at 100 and 500 MHz, Q figures at 100, 200, 400 and 800 MHz and self resonant frequency.

The range available covers values from 1 pF to 1000 pF with dc working voltages between 200 and 500 V. RF current handling ranges from 0.9 A RMS at 500 MHz for the 1 pF device to 20 A RMS for the 1000pF device.

For convenience in prototyping and experimenting, these capacitors are available in a labelled package of two pieces. Prices are currently $4.50 per pack for values of 1 pF to 22 pF, $6.00 per pack up to 100 pF, $10.50 per pack for 470 pF chips and $15.00 per pack for 1000 pF chips. All prices are plus 20% sales tax and are subject to change without notice.

For further information, contact **Stewart Electronic Components Pty Ltd, PO Box 281, Oakleigh 3166 Victoria. (03)543 3733.**



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Specifications Frequency Range: 500KHz — 905MHz Mode: A3[A3E] (AM), F3[F3E] (FM) Circuitry: AM, FM(N) = Triple conversion system FM(W) = Double conversion system Sensitivity: AM (S+N/N = 10dB) = Less than 5 uV (BC band 10uV). FM (N) = 12dB SINAD less than 6uV (500KHz — 60MHz) less than 3uV (60 — 905MHz). Operating Temperature: -10^{0} - $+60^{0}$C. Audio Output Power: 2W (at 8 ohms load 10% distortion). Current Drain: Less than 1A (audio power output 1W). Antenna Impedance: 50 - 300 ohms. Power Requirement: 13.8VDC $\pm$ 15%. Dimensions: 180(W) x 50(H) x 158(D) mm. Weight: 1.5kg.

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The amplitude of solar cycle number 22

Richard Thompson
IPS Radio & Space Services

Last January, we published "Kiss Your Last Big Sunspot Maximum Goodbye". New research may fortunately prove that article's prediction wrong!

IT IS NOW APPARENT that the end of solar cycle number 21 was reached in September 1986 when the yearly smoothed sunspot number dropped to a minimum of 12.4. Since that time the new cycle, denoted cycle 22, has risen strongly and the sunspot number had climbed to 19.4 in February 1987. If this new cycle rises in the average manner of historical cycles, we will reach a maximum sunspot number late in 1990.

The prediction of the sunspot number of the next solar maximum is important. A successful prediction can provide insight into the mechanism by which the solar cycle is generated. The prediction of the amplitude is also important for a number of very practical purposes. For example, a large solar cycle with a high maximum sunspot number supports a wider spectrum of useable HF communication frequencies than a small one. Many of the users of the HF predictions provided by IPS Radio and Space Services require long term predictions to plan their communication systems. A large error in the predicted maximum could result in considerable cost.

The crash of Skylab in July 1979 was a notable example of the result of an incorrect solar cycle prediction. Skylab was launched in May 1973 to an altitude calculated on the assumption that cycle 21 would be a small one. In fact the cycle was large, the second highest on record, and Skylab was subjected to more atmospheric drag than was anticipated. This caused the orbit to decay before the development of the Space Shuttle could support Skylab activities.

A large solar cycle has its disadvantages as well as its advantages. Solar flares are more frequent in a large cycle and these can cause fadeouts of some, or even all, HF communications. Known as short-wave fadeouts, these are important events for over-the-horizon radars such as Australia's Jindalee as well as for ordinary HF communications.

A large solar cycle also produces more frequent disturbances to the ionosphere and the geomagnetic field than a small cycle. These disturbances result from particles ejected from the Sun during energetic events such as solar flares. If the particles reach the Earth they induce currents in the magnetosphere. The effects of these currents on the ionosphere is known as an "ionospheric storm". The corresponding effect on the geomagnetic field is known as a "geomagnetic storm". Ionospheric/geomagnetic storms degrade HF communications, disrupt geophysical prospecting for minerals, produce current surges in power lines, corrosion in pipelines and are associated with anomalies in the operation of satellites. They are sometimes even associated with the loss of homing pigeons!

The prediction of the next cycle

A wide variety of methods have been used to predict the amplitude of a cycle prior to the previous solar minimum. A description of the various techniques is given by Brown (1984a). They include the analysis of the time series of historical sunspot numbers to establish a power spectrum of periodicities. Once established, the series can be extrapolated to generate a prediction of the next cycle. Unfortunately, the solar cycle appears to be highly variable in its behaviour, perhaps even chaotic, and these techniques have had limited success in the past.

Another common technique is that of "secular cycles" in which a long term trend in solar activity is perceived and then extrapolated to the next cycle. An example is the Gleissberg cycle with a period of around 80 years (Gleissberg 1942). Predictions based on the Gleissberg cycle have been indicating a decline in solar activity since the record sunspot maximum in 1957 on the assumption that this was the peak of the Gleissberg cycle. In the 30 years since that maximum we have seen a continuation of strong cycles with a slightly above average cycle (number 20) and then the second largest on record (cycle 21).

Other techniques which have been used include the correlation of solar activity with alignments of the planets or with the motion of the Sun with respect to the centre of mass of the solar system. These techniques have not been very successful in the past and we certainly lack a physical understanding for any such correlations if they exist.

The only prediction methods which have general approval are the "precursor" techniques. These operate on the notion that a solar cycle really begins some years before solar minimum and the first manifestation of the new cycle is the formation of stable large scale magnetic structures known as coronal holes. Coronal holes are sources of streams of high speed solar wind which produce a terrestrial ionospheric/geomagnetic disturbance whenever a stream reaches the Earth. The stability of the coronal holes gives rise to a sequence of disturbances spaced by 27 days, the apparent rotation period of the Sun. Such disturbances are known as "recurrent" and their number, strength and stability in the declining phase of a cycle seem to be useful predictors of the strength of the following cycle.

The connection between recurrent geomagnetic disturbances in the declining phase of a cycle and the strength of the next solar cycle can be seen in Figure 1. This shows the variation of sunspot number since 1930 (dashed line and left scale) and also the number of geomagnetically disturbed days since 1932, (solid line and right scale). A day is considered to be geomagnetically disturbed if the daily planetary A index (Ap) was greater than 24. The level of disturbance appears to vary with two components. Firstly there is a component which is approximately in phase with the solar cycle. These disturbances show only a weak tendency to be recurrent.

Author	Predicted Sunspot Number
Brown (1984b)	120
Kane (1987)	185
Kataja (1984)	140
Sargent (1987)	118
Schatten (1984)	109
Schatten and Sofia (1987)	170
Thompson (1985)	159

TABLE 1.
Some Recent Predictions of the Next Peak sunspot Number

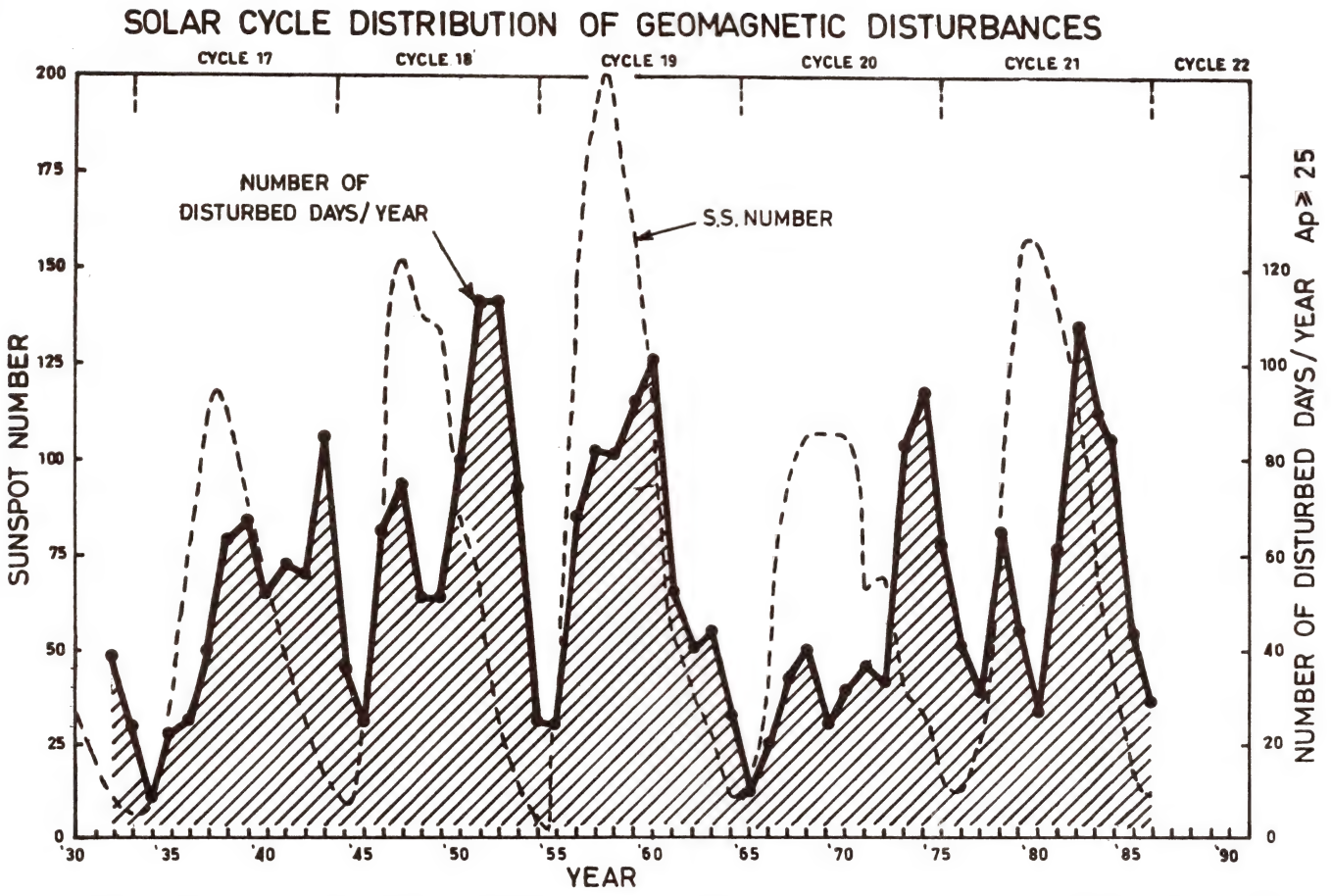

Figure 1. The variation of the yearly-averaged sunspot number since 1930 (dashed line) and the variation in the number of geomagnetically disturbed days since 1932 (solid line).

Secondly there is a component which peaks in the declining phase of some, but not all, solar cycles. For example, two of the largest peaks in Figure 1 occurred in 1951-1952 (just before cycle 19, the highest on record) and in 1973-1974 (just before cycle 21 which was the second largest cycle on record). The disturbances in these peaks exhibited a very strong tendency for recurrence. Both peaks were characterised by "monster" solar wind streams giving rise to two equally spaced disturbances during each solar rotation. These streams were long-lived, lasting for more than a year. In contrast, the declining phase prior to the relatively weak cycle 20 shows evidence of a very small peak of recurrent geomagnetic activity in 1963.

An interesting feature in Figure 1 is the large peak of disturbances visible in the declining phase of solar cycle 21 during the period 1982-1984. The disturbances during this time show a strong tendency to be recurrent but did not show the same general stability as the "monster" streams of 1973-1974. The peak was also strange in that it occurred quite soon after solar maximum as compared with the earlier recurrent peaks. Also, it followed a trough of magnetic disturbance around 1980. This year was quite unusual because, even though it was close to the maximum of the second largest cycle on record, it was a year of very low magnetic disturbance.

In spite of some unusual features it is interesting to predict the amplitude of cycle 22 on the basis of the 1982-1984 disturbance peak. This has been done by Thompson (1985) who predicted a sunspot maximum of 159 for cycle 22.

Other estimates using variants of the precursor technique have shown a fair scatter, but all are above the long term average cycle amplitude of slightly more than 100. Table 1 summarises some recent predictions.

The average sunspot number given by these seven predictions is 143. This is slightly above the value of 130 which has been adopted by IPS for its long term HF predictions.

Table 2 lists the current IPS predicted sunspot numbers for the next ten years. These are based on a peak sunspot number of 130 and a cycle shape equal to the average of cycles number 8-20. It is important to stress that any variation in the amplitude or the shape of the actual cycle could produce considerable differences from the predictions in Table 2.

Date	SSN
June 1987	23
June 1988	57
June 1989	109
June 1990	130
June 1991	125
June 1992	106
June 1993	72
June 1994	51
June 1995	33
June 1996	20
June 1997	10

TABLE 2. Predicted sunspot Numbers for the Next Ten Years

The rise of solar cycle number 22

After solar minimum it is possible to predict the ensuing solar maximum purely from the rate of rise of the cycle, e.g: McNish and Lincoln (1949). Naturally, such predictions are more accurate, but less predictive, when there is a long elapsed time from solar minimum. We have now seen 11 months of the new cycle ▷

and have seen bursts of solar region growth in October 1986, April-May 1987 and in July-September 1987.

Figure 2 shows the regression between the rise in sunspot number in the first 11 months of a cycle and the ultimate peak sunspot number. The dots are observed values for the 21 solar cycles for which we have reliable monthly sunspot data and the solid line is the least square best fit line. (A "least square best fit" is mathematical technique for finding the "trend" in scattered data – Ed.). The dashed vertical line is the value observed for the present cycle.

It is very interesting to note that the present cycle has risen much faster than any of the previous cycles. However, at this early stage, the correlation of cycle rise and ultimate sunspot number is still very weak and the relationship is affected significantly by factors such as the shape of the cycle, the height of the minimum and perhaps the amplitude of the previous cycle (which might delay or advance solar minimum depending on its amplitude). With these limitations, the data in Figure 2 can be used to estimate the cycle amplitude and a value of 156 ±42 is obtained. The uncertainty in this figure probably only entitles us to say that the cycle will be above average in amplitude, as has been predicted by the precursor techniques. However, within 6 to 12 months, this method should be capable of predicting the cycle amplitude with an accuracy of ±20 in sunspot number.

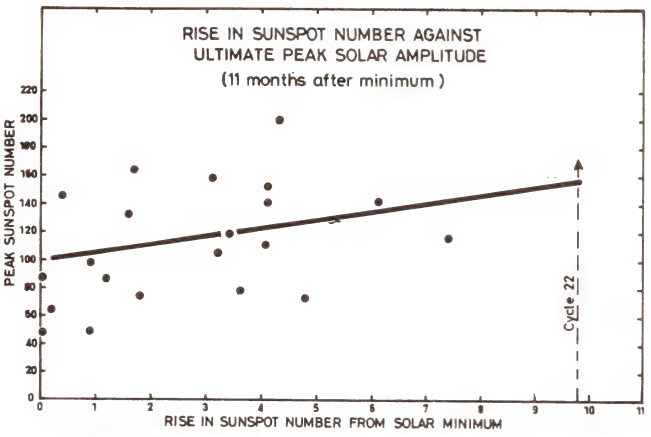
RISE IN SUNSPOT NUMBER AGAINST
ULTIMATE PEAK SOLAR AMPLITUDE
(11 months after minimum)
PEAK SUNSPOT NUMBER
RISE IN SUNSPOT NUMBER FROM SOLAR MINIMUM
Cycle 22

Figure 2. The rise in the sunspot number in the 11 months after solar minimum plotted against the eventual maximum sunspot number of the solar cycle.

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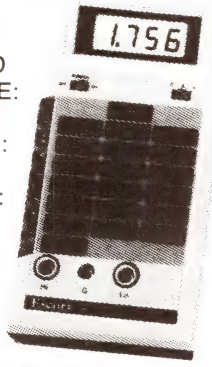

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Elektor Electronics in AEM

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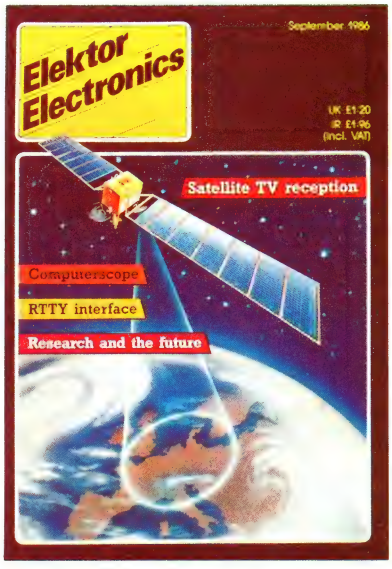

The projects and circuits chosen for inclusion in the Elektor section are selected on the basis of interest, local relevance and component availability. Intending constructors should consult our 'PROJECT BUYERS GUIDE' in this issue for a guide to component sources and possible kit suppliers.

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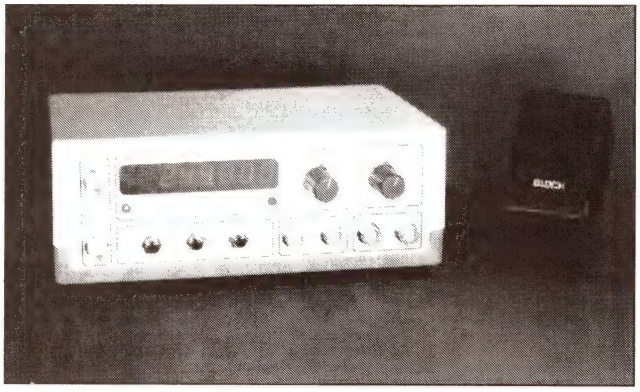
MULTI-FUNCTION FREQUENCY METER

An advanced, versatile and user-configurable test instrument capable of accurate measurement of frequency, frequency ratio and time interval. In addition to all this, it can be used as a period and event counter.

The multi-function test instrument described here is based on the 8-digit counter/timer IC Type ICM7226B from Intersil (GE/RCA). This chip combines all the functions expected from a good and versatile counter, and requires very few external components. The chip handles frequency measurement from DC to 10 MHz, period measurement from 0.5 μs to 10 s, unit counting up to 10 million events, frequency ratio measurement, and time interval measurement. The inputs of the proposed instrument can accept a wide range of alternating (analogue) voltages as well as digital pulses at TTL or CMOS levels.



Circuit description

The circuit diagram of the frequency meter is given in Fig. 1. It would be beyond the scope of this article to give a detailed description of the internal operation of the ICM7226B, and the following is, therefore, an outline of the simple peripheral circuitry needed to obtain a complete instrument. A prescaler for extending the input frequency range to 1.2 GHz will be discussed in a forthcoming issue of *Elektor Electronics*.

The ICM7226B has internal timebase circuitry, display decoders, segment and digit drivers. The 8-digit read-out is composed of common cathode LED displays multiplexed at 500 Hz and a duty factor of 0.122 per digit. Leading (non-significant) zeroes are blanked when the meter is set to frequency measurement in kHz or period measurement in μs. LED D_9 indicates an overflow condition, i.e., the counter is "full", and all digits read 9.

The counter, IC_3, has an on-chip timebase oscillator which operates at 10 MHz (X_1). It is possible to use a 1 MHz quartz crystal provided S_8 is closed. Similarly, S7 makes it possible to apply an external clock signal of 100 kHz or more to pin 33. When switch S_6 is closed, the position of the decimal point on the display is controlled externally via the respective input, pin 20. The decimal point can thus be positioned as required for the prescaler used. Switches S_6-S_7-S_8 and the associated diodes, D_6-D_7-D_8, are intended for the above options on the frequency meter, and may be omitted when the relevant function is not required. It is, of course, also possible to replace the switches with wire links for permanent operation in a particular mode.

The maximum input frequency applied to input A of the instrument is 10 MHz in the *frequency* and *unit count* modes, and 2 MHz in the other modes. The counter modes and functions that can be selected with the RANGE switch, $S_{4a\text{-}b}$, and the FUNCTION switch, $S_{2a\text{-}b}$, are summarized in Table 1. Position 6 of S_2 is used for checking whether the internal oscillator works, but not for veryfing the frequency of oscillation. It should be noted that input B is only used for measuring frequency ratios and time intervals. The frequency of the signal applied to input A should be higher than that applied to B. Similarly, the pulse transition on input A should occur before that on input B.

Table 1

Switch S_2: FUNCTION	
Position	Function
1 (K1)	frequency (f_A)
2 (K8)	period (T_A)
3 (K2)	frequency ratio (f_A/f_B; $f_A > f_B$)
4 (K5)	time interval ($t_A \rightarrow t_B$)
5 (K4)	unit counter
6 (K3)	oscillator test

Switch S_4: RANGE	
Position	Accumulation time / cycle(s)
1 (K1)	0.01 s / 1 cycle
2 (K2)	0.1 s / 10 cycles
3 (K3)	1 s / 100 cycles
4 (K4)	10 s / 1,000 cycles

The protective networks fitted at the inputs of N_5 and N_6 enable applying alternating voltages as well as CMOS or TTL (digital) pulses. For small alternating voltages applied via C_1-C_2, diodes D_1-D_2 or D_3-D_4 do not have a limiting effect, so that inverters N_5-N_6 operate as amplifiers. When the input amplitude is greater than about 2 V_{pp}, the inverters operate as buffers. Limiting of the input signal takes place when the input signal at the digital inputs is lower than −0.6 V or higher than +5.6 V. This means that AC coupled input voltages are clipped to about 6 V_{pp}. The input sensitivity stated in the circuit diagram is an average and frequency dependent value. When the Type 74HCT04 in position IC_2 ($N_5 \ldots N_{10}$ incl.) is replaced with a 74HCU04, the input sensitivity increases by a factor 5 to 10.

The circuit around $N_7 \ldots N_{10}$ incl. and XOR gates N_3-N_4 is used for measuring time intervals, i.e., the period that lapses between the positive edges of the signals applied to inputs A and B. A bistable internal to the ICM7226B is set and reset by the pulse transitions at input A and B, respectively. When the bistable is set, the oscillator pulses are internally fed to the counter input. Evidently, the longer the bistable remains set,

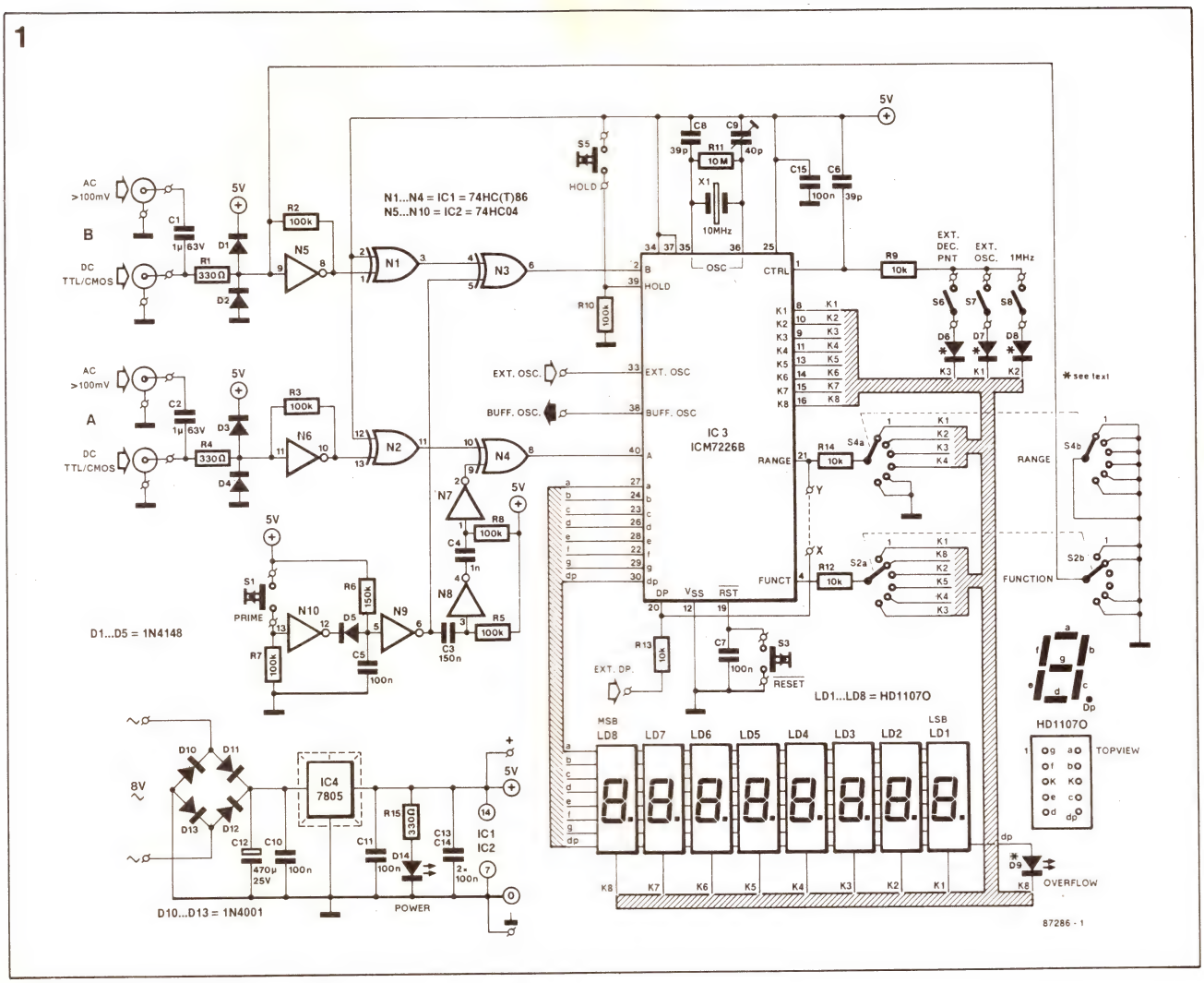


Fig. 1 Circuit diagram of the multi-function frequency meter.

the more pulses are counted, and the higher the read-out on the display. Push-button PRIME is pressed before measuring the time interval for a single event. Inverters N_{10}-N_9 generate a brief pulse for chip input A; N_8-N_7 a slightly delayed pulse for input B. The internal logic in the ICM7226B is thus primed ready for measuring the interval for one event, delimited by the positive edges of the pulses applied to instrument input A and B. Pressing PRIME is not required when these inputs are driven with a repetitive signal, as the first alternating signal states cause automatic priming of the counter chip.

The read-out can is retained ("frozen") as long as the HOLD switch, S_8, is pressed. The counter's internal circuits—and hence the read-out— can be cleared at all times by pressing the RESET key, S_3. Capacitor C_7 is connected in parallel with S_3 to prevent hang-ups at power on. The 3 push-buttons can be fitted on the counter's front panel as suggested in Fig. 2. The power supply for the frequency meter is of conventional design, and requires no further detailing.

Construction

Virtually all parts shown in the circuit diagram are fitted on a single printed circuit board, whose track layout and component mounting plan are shown in Fig. 3. Commence the construction with fitting all the wire links. Do not forget the 8 short ones underneath the displays! Electrolytic capacitor C_{12} is fitted at the track side of the board. Make sure that it is fitted securely and slighly off the board to prevent sharp solder points piercing the insulating material and causing short-circuits with the grounded metal can. It is recommended to use good quality sockets for all integrated circuits. The displays are also fitted in 10-way sockets, made from terminal strips or 14-way IC sockets. Use

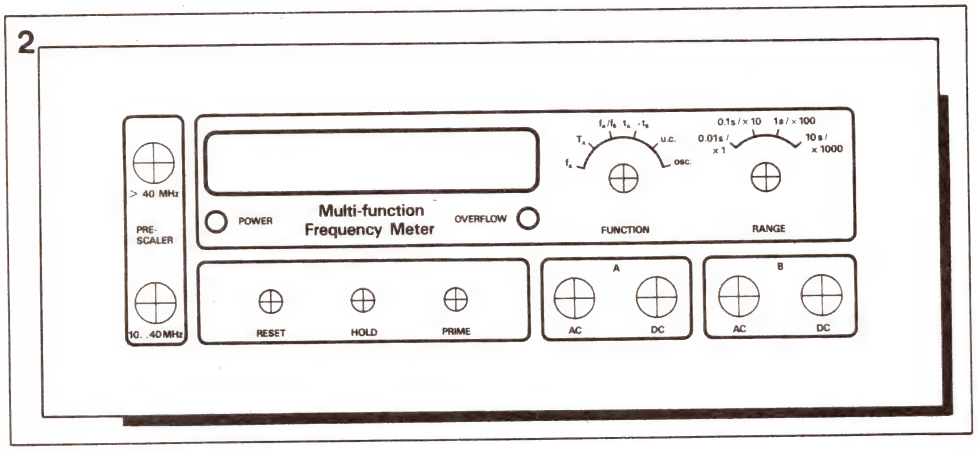


Fig. 2 Lay-out of the ready-made front panel foil for the frequency meter.

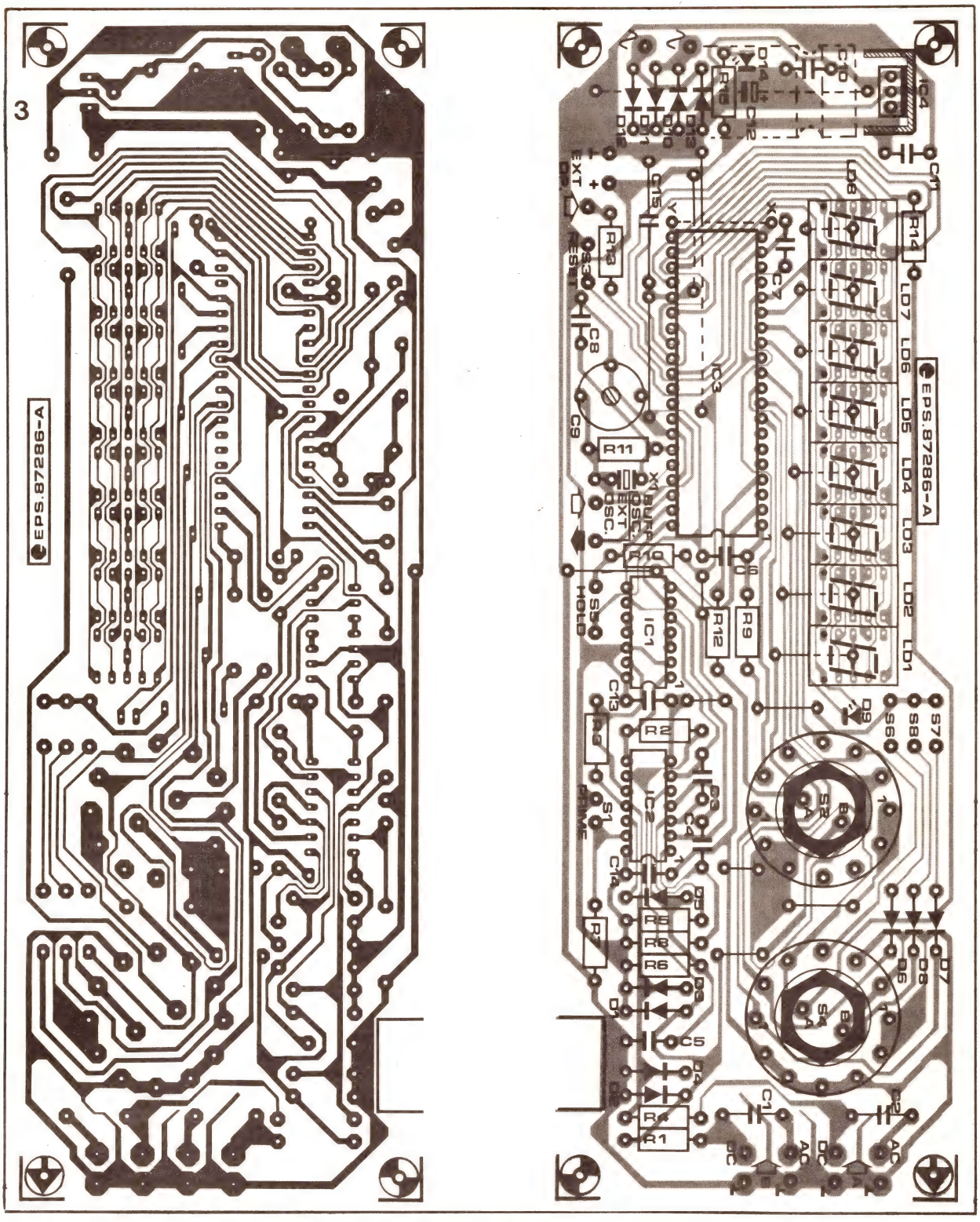
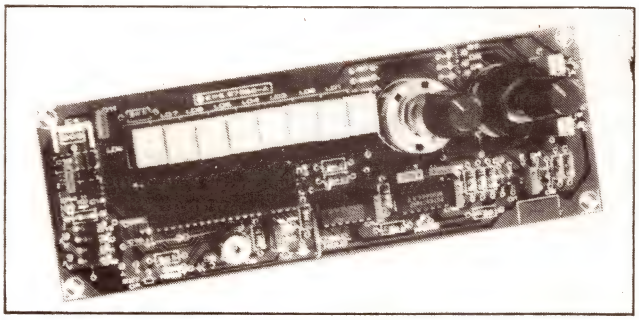


Fig. 3 Track layout and component overlay of the PCB for building the frequency meter. Capacitor C_{12} is fitted AT THE TRACK SIDE.

short lengths of strong wire to ensure the correct height of the displays above the board. LED D_9 is a high brilliance type whose leads are lengthened make its top is level with the displays in the sockets. Voltage regulator IC_4 should be mounted with a heat-sink. The RANGE and FUNCTION switches, S_4 and S_2, are soldered direct onto the board, or with short lenghts of left over component wire, to minimize stray inductance and capacitance. This measure effectively prevents unwanted effects such as indeterminate illumination of digits ("ghosting"). As already stated, function switches S_6-S_7-S_8 may not be required on the front panel of the instrument. Inputs A and B are made in flange-type or single hole BNC sockets. Two more of these are required when it is intended to



The completed printed circuit board (prototype version).

Parts list

Resistors (±5%):
R1;R4;R15 = 330R
R2;R3;R5;R7;R8;R10 = 100K
R6 = 150K
R9;R12;R13;R14 = 10K
R11 = 10M

Capacitors:
C1;C2 = 1μ; 63 V (non-electrolytic)
C3 = 150n
C4 = 1n0
C5;C7;C10;C11;C13;C14; C15 = 100n
C6;C8 = 39p
C9 = 40p trimmer
C12 = 470μ; 25 V

Semiconductors:
D1 . . . D5 incl. = 1N4148
D6;D7;D8 = 1N4148 (see text)
D9 = high brilliance LED (red)
D10 . . . D13 incl. = 1N4001
D14 = red LED
IC1 = 74HC86 or 74HCT86
IC2 = 74HCU04 or 74HCT04
IC3 = ICM7226BIJL or ICM7226BIPL+
IC4 = 7805
LD1 . . . LD8 incl. = common cathode LED display HD11070+

Miscellaneous:
S1;S3;S5 = push-to-make button.
S2 = 2-pole 6-way rotary switch for PCB mounting.*
S4 = 2-pole 4 or 6-way rotary switch for PCB mounting.*
S6;S7;S8 = miniature SPST switch (see text).
X1 = 10 MHz quartz qrystal.
TO220 style heat-sink for IC4.
Verobox enclosure Type 4775-1411.
Mains transformer 8 V; 0.5 A.
Mains entrance socket, fuse (100 mA), and DPDT switch.
Knobs for rotary switches.
BNC sockets as required.

* Switch with adjustable stop, e.g. Lorlin Type CK1045

See our 'PROJECT BUYERS GUIDE' this issue for a guide to component sources and kit suppliers.

extend the frequency meter with the prescaler to be introduced. Inputs EXT. OSC, EXT. DP, and output BUFF. OSC, can be made in suitable sockets on the rear panel of the enclosure. The signal at BUFF. OSC can be used for setting the oscillator frequency to 10.000 MHz precisely with the aid of trimmer capacitor C9. It is also possible to use the signal for driving other circuits, provided the BUFF. OSC output is fitted with a 10K resistor to the +5 V rail.

The supply voltage for the prescaler is available on 2 soldering pins next to the EXT. DP input.

The completed PCB is mounted vertically in the moulded guides provided in the bottom plate of the Vero enclosure. The ready-made front panel foil for the frequency meter can be used as a template for drilling the metal front panel provided with the enclosure. The shafts of the rotary switches, S2 and S4, are cut to size to enable fitting suitable knobs. The LED displays are fitted in a rectangular clearance cut in the front panel. The visibility of the read-out is enhanced by the semi-transparent bezel in the ready-made front panel foil. The OVERFLOW indicator, D9, is fitted immediately below the right-hand side of the display bezel. The position of the various controls and indicators is evident from Figs. 2 and 4.

It is, of course, possible to use a ready-made mains adapter with 8 VAC output for powering the instrument. In many cases, this is safer and less expensive than incorporating a mains transformer. When it is still intended to furnish the frequency meter with its own, internal, mains supply, the mains socket and fuse (100 mA) should be fitted at safe locations onto the rear panel of the enclosure. The mains transformer should be preferably an 8 V, 0.5 A type. The current consumption of the circuit is about 55 mA with all displays blanked, and 175 mA with all displays illuminated. ◀

Reference:

Component Data Catalog 1987: ICM7226A/B p. 14-80 ff. Intersil GE/RCA International Limited • Beech House • 373-399 London Road • Camberley • Surrey GU15 3HR. Telephone: (0276) 685911. Fax: (0276) 685255.

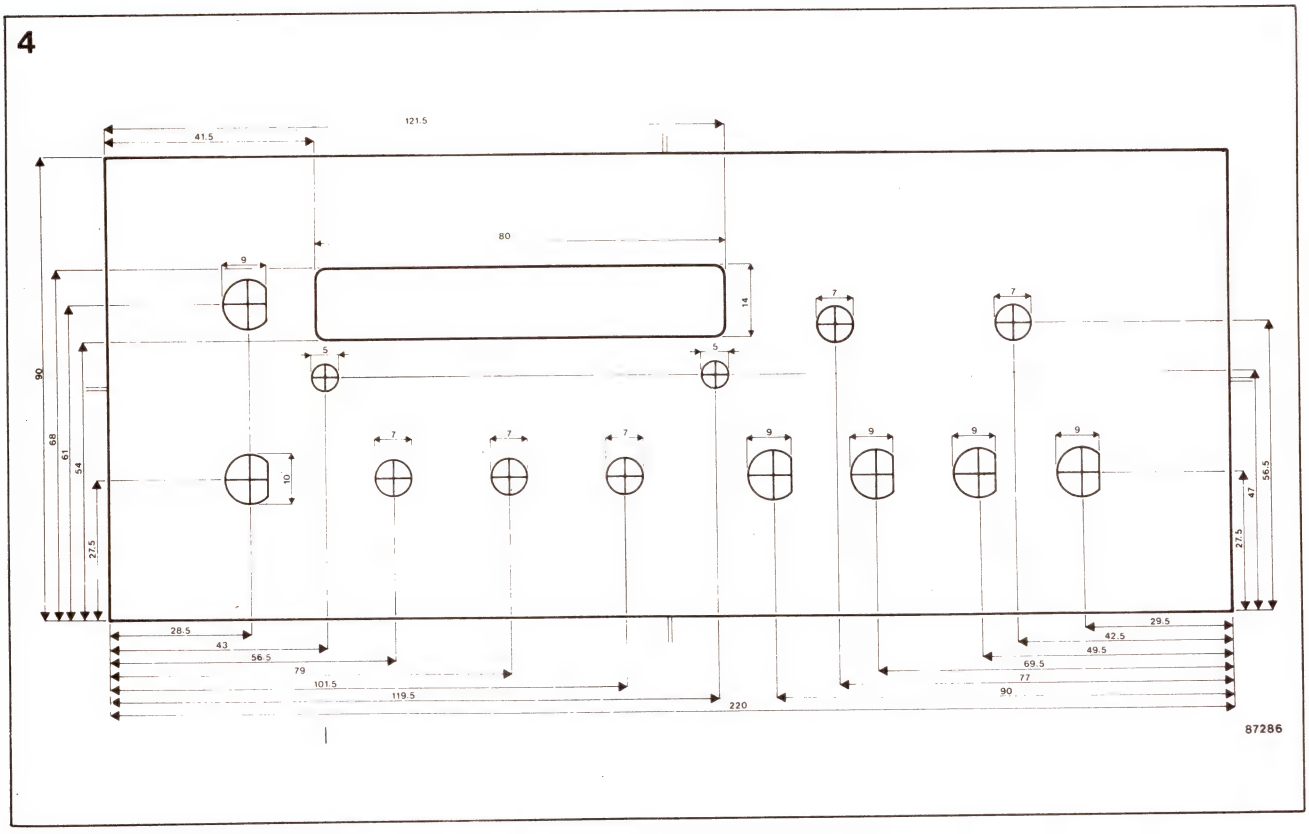


Fig. 4. Drilling diagram for the front panel.

BRITISH AEROSPACE: 10 YEARS IN SPACE

When we speak of British Aerospace, we normally think of Concorde and the company's other work in aircraft production and engineering. But, in the first 10 years of its existence, this industrial giant has also become world renowned for its work in space engineering and electronics.

British Aerospace was born on 29 April, 1977, by the amalgamation of British Aircraft Corporation, Hawker Siddeley Dynamics, and Scottish Aviation, companies whose antecedents can be traced back to the dawn of powered aviation in the first decade of this century.

Lord Beswick was its first Chairman. He was succeeded in March 1980 by Sir Austin Pearce. This was the final year in which BAe operated as a nationalized corporation. On 1 January, 1981, the business was vested in British Aerospace PLC.

In 1983, Sir Raymond Lygo was appointed Managing Director of BAe, and in 1985, the year that BAe was fully privatized, he was appointed its Chief Executive.

Today, BAe is the UK's largest exporter of manufactured goods, with an order book approaching £10 billion. By comparison, the order book in 1977 stood at £2 billion. Then, sales were £800 million, of which £530 million were exports. Today, the respective figures are £3.1 billion and over £2 billion.

BAe has established itself as Europe's largest aerospace company with the widest range of products of any such company anywhere in the world. Its portfolio of products stretches from underwater systems, through ship-launched missiles, ground-launched missiles, military aircraft and air-launched missiles, civil airliners and business aircraft, to satellites for communications and scientific research.

This position owes much to the substantial investment British Aerospace has made in developing a total product strategy, which is most evident in the launch of no fewer than six new civil aircraft programmes.

Although British Aerospace consists of seven divisions, employing a stable workforce averaging 75,000 people, this article deals primarily with the Space and Communications Division at Stevenage, employing around 1,600 people, but a brief summary of the activities of the Electronics and Equipment Division (3,200 personnel) is also given.

Electronic Systems and Equipment Division

The Division produces a wide range of navigation and guidance systems for land, sea and aerospace use, plus data handling, message switching and electronic warfare systems.

A new activity is the development of antismuggling cargo examination systems.

Avionic products include laser gyro inertial navigation systems, strapdown attitude and heading reference systems, gyrocompasses, twin-gyro platforms, flight instruments, crash-protected flight data recorders and engine health monitors.

Missile aerodynamic and rocket-thrust vector control systems are supplied as well as electro-hydraulic power units. Missile gyroscopes produced include the Microflex gyro.

Sea Archer gunfire control systems are supplied for naval ships. The Interceptor surveillance and gunfire control system for offshore patrol craft is offered. Compass equipment and vertical reference units for ships are also available.

A field artillery battery computer is manufactured for the Swiss Army. Tilt sensors are supplied for tanks. Ajax is a sensor and fire control system for anti-armour off-route mines using LAW-type projectiles.

Data handling, message switching and disc memory systems are built. A Royal Navy main communication centre has been equipped with an advanced message switching system, and smaller message switching and formatting systems are made for naval vessels.

An infra-red jammer for helicopters to counter infra-red missiles is available. Electronic warfare, electronic warfare simulation, electronic support measures, allied with experience in communications and message handling, provides the Division with a C^3I capability.

Antennas and antenna systems are produced for aircraft, land vehicles and ground based use.

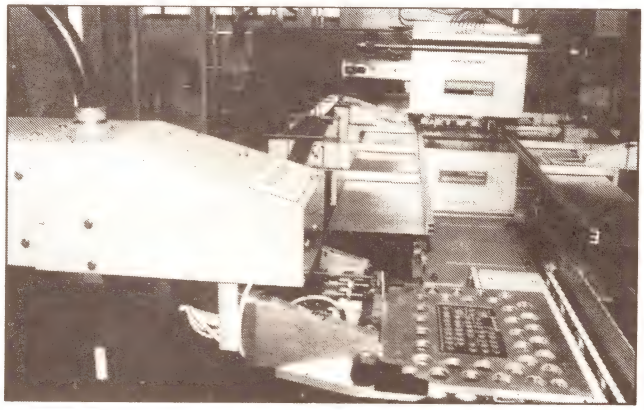


Fig. 1. Flexible manufacturing system for the automated production of electronic units.

Space and Communications Division

British Aerospace is Britain's leading space engineering contractor, and the Division is the largest organisation of its type in Europe. It has its headquarters at Stevenage where work on the design and construction of communications satellites is concentrated.

Communications satellites in service for which the Division was prime contractor include OTS (now retired), Marecs-A and B2, and ECS-1 and 2. The Division is responsible for a further nine communications satellites now under construction. These are ECS (2-off) Skynet 4 (3-off), Olympus and Inmarsat 2 (3-off). As principal subcontractor, the Division is also participating in the largest contract for communications satellites yet placed. It is to build Intelsat VI satellites. The Eurostar communications satellite is also marketed in association with Matra.

Other projects of the Division are Hotol (horizontal take-off and landing launcher), and Space Platform, a free-flying vehicle to operate in conjunction with manned space stations.

The Division also includes a major space engineering facility at Bristol concerned with scientific satellites and equipment, the development of solar arrays, and the Skylark soun-

ding rocket. Giotto, the Halley's Comet spacecraft, was built there along with units for the NASA/ESA Hubble Space Telescope. The Division is involved in numerous other space engineering projects as a major supplier of systems and equipment.

European Communications Satellites

The European Communications Satellites (ECS) provide a European communications network for telephone, telex, business data, facsimile, and TV traffic. The programme calls for five satellites in all, of which ECS-1 and ECS-2 are in service. ECS-3 was lost because of an Ariane launcher failure in September 1985. ECS-4 was launched, together with AUSSAT (an Australian communications satellite) in the early hours (BST) of 16 September last by Ariane 3. It is at present being tested before it is taken into service and will then be designated Eutelsat 1-F4. Its geosynchronous position will be 10° E.

These satellites are operated by the European Space Agency for Eutelsat—the 20-nation assembly of European PTTs—and for the Europeam Braodcasting Union (pan-Europe TV). They contain 12-14 transponders capable of handling up to 12,600 telephone circuits and two TV transmissions. Their power (1,200 W) is derived from 13.8 m-span solar arrays.

Maritime Communications Satellites (MARECs)

The role of MARECs is to provide global communications between ships and shore stations. MAREC-A was launched in December 1981 and is operating in geosynchronous orbit positioned over the Atalantic at 26° W. The first MAREC-B was lost in September 1982 due to a failure of the Ariane launcher. Its replacement was launched on 10 November, 1984. It is positioned in geosynchronous orbit over the Pacific at 117.5° E.

The satellites have one 2 m diameter dish for ship-to-satellite communications in the 1.5 GHz and 1.6 GHz bands, and two horns for satellite-to-shore transmissions in the 4 GHz and 6 GHz bands. Power (750 W) is derived from 13.8 m-span solar arrays.

MARECs are operated by the European Space Agency and used by INMARSAT—the multinational International Maritime Satellite Organization.

Olympus

Olympus satellites are large multi-purpose, high—power communications satellites with direct broadcast capabilities. Members of the Olympus family will vary in size and weight, and power-generation and communications facilities, according to the particular operational role for which it is required. The largest versions could generate 7.7 kW from solar arrays of 60 m span.

Olympus satellites can be equipped with up to fifty 50 W transponders capable of handling 200,000 half-telephone circuits or the equivalent facsimile, telex, data, and TV transmissions, or up to 12 fullpower direct broadcast TV services. Typical communications frequencies are direct-broadcast TV 11.7-12.5 GHz; specialized business services: uplink 14-14.25 GHz, downlink 12.5-12.75 GHz; high-power communications 20 to 30 GHz.

Olympus-1 has a pre-operational direct-broadcast TV channel for Italy and a second steerable channel for experimental use by members of the EBU. It will be launched from Kourou, French Guyana, in the near future and be positioned in geosynchronous orbit at 19° W.

Under the leadership of the Space and Communications Division, an international consortium comprising Aeritalia, Selenia-Spazio, Fokker, and Spar Aerospace will build Olympus communications satellites and market them worldwide.

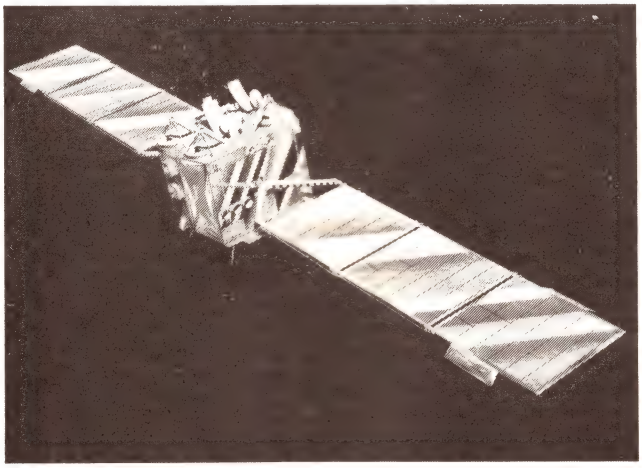


Fig. 2. European Communications Satellite.

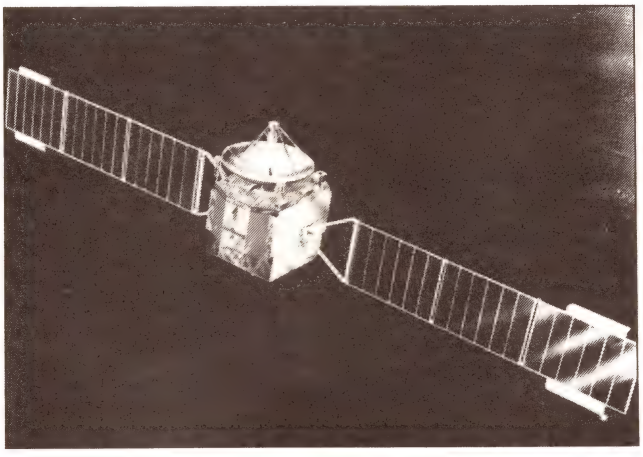


Fig. 3. Marec maritime communications satellite.

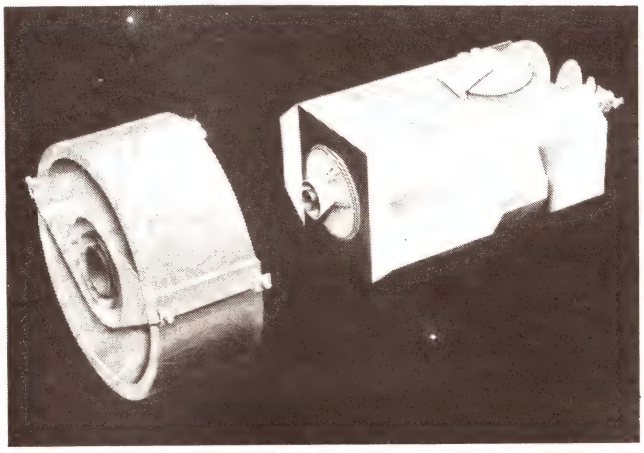


Fig. 4. Satellite transfer vehicle (single launch).

Eurostar

Eurostar is a medium-size satelite, larger than ECS-class satellites, but smaller than the Olympus series. It can be carried by, and launched from, Space Shuttle Orbiters, or it can be one of two satellites launched by Ariane, being carried aloft on the Ariane's Spelda structure specially developed by BAe for dual-launch missions.

Eurostar is the first product of Satcom International, a joint venture of BAe and Matra of France to design, build, and supply communications satellites on the international market.

Eurostar can accommodate communications payloads up to 250 kg mass and supply them with 700 W RF power. Maximum power generated by its solar arrays is 3.2 kW.

Skynet 4

Skynet 4 is a series of military communications satellites for the UK armed forces. Its design is based on that of ECS with communications equipment operating in the X-band supplied by Marconi. Each satellite's 16 m of solar arrays

generates 1,200 W of electrical power. The first two satellites in the series are launched by Space Shuttle.

INMARSAT-2

Inmarsat-2 is a family of second-generation maritime communications satellites being built for the International Maritime Satellite Organization. Although the initial contract calls for three satellites, options exist to supply a further six.

The satellites provide 250 voice channel for ship-to-shore communications, and 125 voice channels for shore-to-ship links. Ships' terminals operate in the L band (1.5 to 1.6 GHz), while shore stations use the C band (3.6 to 6.4 GHz). Hughes Aircraft is supplying the satellite communications payload.

The Inmarsat-2 design is based on that of Eurostar. These satellites have a design life of 10 years and can be launched by Ariane or Space Shuttle.

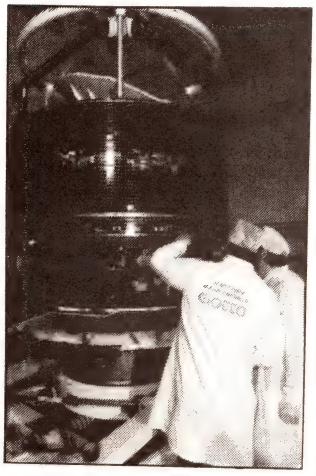


Fig. 6. Giotto — the Halley's Comet spacecraft.

NATO IV

BAe is designing two military communications satellites for NATO. Given the designation NATO IV, these satellites will provide members of the alliance with secure military and diplomatic communications facilities. The first NATO IV is scheduled to be launched in the early 1990s. Both will remain in service beyond the year 2000.

In design, the NATO IV satellites are virtually identical to Skynet 4.

Intelsat Series

Intelsat, a consortium of over 100 nations, provides international communications services by satellite. Structures for the Intelsat III series were supplied in an association with this series of communications satellites dating back to 1966. Subsequently, BAe's involvement increased and it became the principal overseas contractor in the Intelsat IV and IVA programmes. BAe was also the only non-Amercian contractor to supply equipment for the US domestic Comstar satellites developed from the Intelsat IV design.

BAe is the principal offshore contractor to Hughes for the Intelsat VI programme. Spacecraft structures, power electronics, cable harnesses, C and K band antenna reflectors, and the complete cradle for supporting and launching spacecraft from Space Shuttles will be supplied for this programme.

The C-band dish, three metres in diameter, is one of the largest antennas made from carbon fibre to be constructed for use in space. The antenna must withstand the harsh conditions of satellite launch and remain dimensionally stable in space, retaining its accurate profile, despite daily temperature changes from −150 °C to +140 °C.

The Big Communicator

The geosynchronous orbit in which communications satellites are positioned is already becoming crowded. This is especially true of sectors in which satellites are placed to cover specific geographical areas generating high volumes of communications traffic, such as Europe and North America. The demand for communications services provided by satellites is increasing and within the next 15 to 20 years the network could be saturated unless some technological solutions are found to expand the available capacity.

Following studies of the problem one answer proposed by British Aerospace is to establish clusters of satellites at particular orbital stations. The separate satellites forming a cluster would be dedicated to fulfilling different roles. An initial cluster could comprise three satellites. One to provide direct broadcasting services, a second communications with mobile vehicles, and a third communications with fixed ground stations. As the traffic associated with a particular region increased, extra satellites of the required type could be added to a cluster to provide the extra facilities needed.

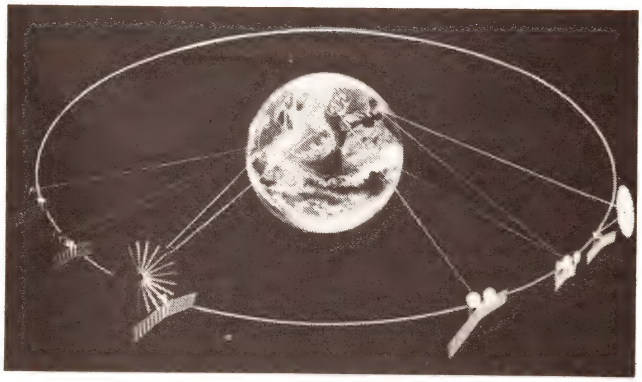


Fig. 5. Big Communicator satellite clusters.

All the satellites of a cluster would be able to intercommunicate, information being relayed between them via laser links to avoid interfering with the communications traffic between the satellites and Earth. Laser links would also be employed to relay communications between adjacent satellite cluster.s This would enable a connection to be established directly between two users on different continents, situated remotely from each other, without the need for multiple Earth-satellite-Earth hops to be set up, as is now the case.

This concept of satellites operating in clusters has been named the Big Communicator by British Aerospace.

The geometry of Big Communicator satellites differs from present-day satellite designs. With the latter, if it is a three-axis stabilised spacecraft, the solar arrays are aligned North to South. In contrast, the solar arrays of the equivalent Big Communicator satellite are aligned East to West and remain fixed pointing at the Sun. They are attached to an open framework which comprises the outer body of the satellite.

Mounted on bearings inside this framework is a drum that contains the satellite's communications equipment and other systems. The communications antennas are deployed from one end face of the drum, the rotation of which is controlled so that the antennas always point towards Earth. One advantage of this layout is that the drum is shielded by the solar arrays from the direct rays of the Sun. Better heat dissipation from the interior of the satellite is also obtained through the drum's ends which permanently face outer space.

Giotto

Launched on 2 July 1985 from

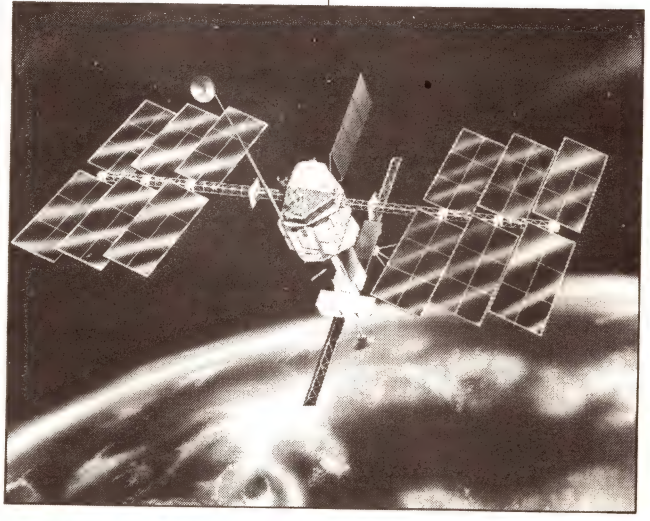


Fig. 7. Columbus space platform.

Kourou by Ariane 1, Giotto was initially placed in a geosynchronous transfer orbit, following which it was boosted into a heliocentric trajectory to intercept Halley's Comet.

Giotto intercepted Halley's Comet during the night of 13 March 1986. Conditions became increasingly hostile during the encounter. Giotto penetrated the dust cloud surrounding the nucleus and because Giotto and Halley's Comet orbit the sun in different directions, this occurred at the very high relative velocity of 68 km/sec (about 150.000 mile/hour).

Giotto's mission was the most successful space science event of 1986. Of the five satellites sent to observe the comet, Giotto made the closest approach, passing within 608 km (378 miles). Close-up photographs relayed back to Earth by Giotto show a potato-shaped object measuring 16 km by 8 km by 7.2 km. The nucleus is very porous with a densitity less than that of water. The comet rotates once every 53.5 hours and has a very dark surface that reflects only 3% of the incident sunlight. The pictures taken by Giotto show clearly a number of active areas from which masses of gas and dust are continuously ejected. Evidence indicates that Halley's Comet consists mainly of water (80%), with carbon dioxide as the next most abundant compound.

Other experiments carried out by Giotto measured the chemical composition, size and abundance of dust grains, and the surrounding atmosphere of electrically charged particles.

Giotto continues in orbit and will arrive back in the vicinity of Earth in 1990, when it may be given another scientific task to perform, such as intercepting Comet Grigg-Sjellerup in 1992.

Ulysses

BAe has developed attitude and orbit control equipment and the 1.6 metre high-gain antenna for Ulysses, the European satellite to be used for the deep-space International Solar Polar Mission. During the 4.5 years of this mission, the satellite will use the gravitational pull of Jupiter to swing it out of the ecliptic place over the poles of the Sun. The satellite's mission is to investigate the solar wind and solar magnetosphere, the structure of the sun/wind interface, the interplanetary magnetic field, solar and galactic cosmic rays, and dust. The magnetosphere of Jupiter will be examined on the way.

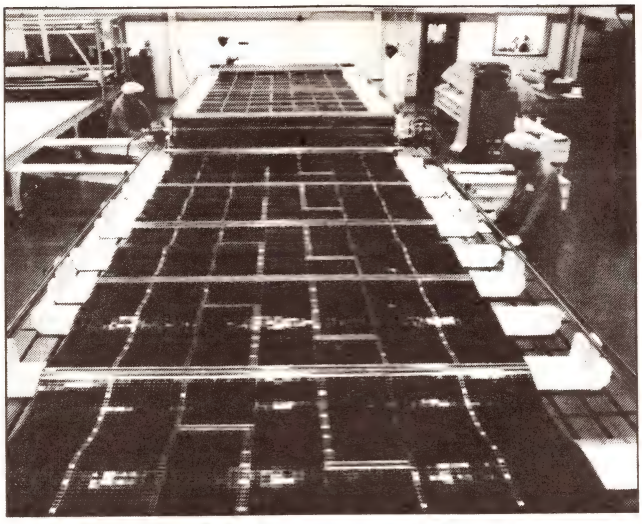


Fig. 8. Space telescope solar arrays being tested.

Hipparcos

Hipparcos is being built for ESA and is Europe's first astronomic satellite. It will accurately measure the positions and proper motions of more than 100,000 stars.

BAe is supplying the power system and electrical distribution network and, with Matra, the attitude and orbit control units for the satellite.

Hipparcos has a design life of 2.5 years and is scheduled to be launched by Ariane in the course of next year.

Hubble Space Telescope

The Hubble Space Telescope will enable objects to be observed that are over seven times further away than can be seen with terrestrial telescopes. The universe accessible to telescopic observation will be increased by the huge factor of 350, and objects 14 billion light years distant will be seen.

Under contract to the European Space Agency (ESA), (BAe) designed and built the solar arrays for the NASA/ESA Hubble Space Telescope to be launched into orbit by a Space Shuttle. These are the largest solar arrays to be constructed in Europe. The total area of the two arrays is 60sq metres. (For further details see entry on Solar Arrays).

BAe has also developed and made the ultra senstive Photon Dectector Assembly (PDA) which is the sensor of the faint object camera, one of the five focal plane experiments associated with the Hubble Space Telescope. The PDA detects individual photons emanating from the object under observation so that a visual image of the source can be built up revealing objects 50 times fainter than those now visible from the Earth.

Space platform

Space Platform is a British Aerospace concept that was proposed by Britain and adopted by the European Space Agency as one of the four major projects in the European Columbus programme which could be part of Europe's contribution to the manned space station being developed by NASA. The Platform would provide the station with an equipment carrier, controlled to operate with it, but at a sufficient distance for the Platform not to be affected by the contamination and clutter surrounding the station, or to impede visiting traffic. Whenever required, Space Platform could be manouevred to dock with the station. As a free flyer, the Platform could be placed in a polar orbit for Earth observation applications or be controlled to co-orbit with the space station. It could also fly at higher or lower altitudes than the station, depending upon the requirements of the equipment being carried.

Space Platform is a vehicle that can be replenished and, if necessary, refurnished in orbit to act as a permanent satellite bus in space. The Platform would provide all the services required for a variety of payload modules. These would be carried up from Earth by Space Shuttle, or a similar reusable launch system, and attached to the Platform. At the conclusion of their missions, the modules would be retrieved and returned to Earth. Typical payloads would be communications equipment, astronomical instruments, Earth observation sensors, material manufacturing systems, biological experiments and other scientific equipment.

The main structure of the Platform and all the systems could be carried up to low-Earth orbit and assembled there during one Space Shuttle mission. During a second mission the payload modules would be added. The Platform has its own propulsion system which would be used to move it into the desired orbit.

Space Platform is designed to be extendable. Initially the Platform could, typically, have four payload module berthing points, generate up to 5kW electrical power, have a fully active cooling system and a data communications link, via a data relay satellite, operating at

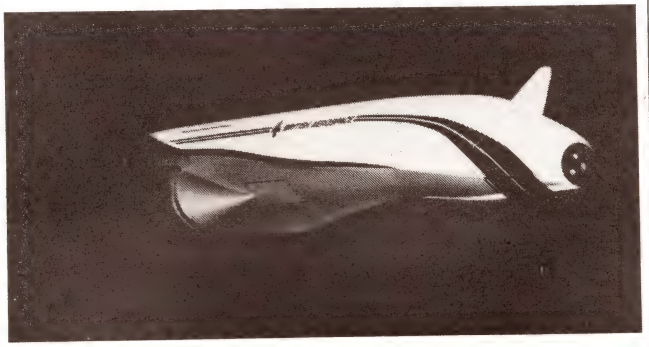


Fig. 9. Hotol.

up to 300 MBPs. It would orbit at altitudes between 600 and 800km.

Hotol

Hotol (horizontal· take-off and landing launcher) is an unmanned reusable single-stage vehicle for placing spacecraft in low-Earth orbits. It will be capable of lifting payloads up to 7000kg mass transported in a cargo bay 4.5m in diameter by 9m long. In effect, Hotol is an unmanned aircraft powered by an air-breathing and rocket propulsion system. It can take-off and land-on runways from which the Concorde could operate.

It is proposed as a more economical vehicle than the Space Shuttle for the task of launching spacecraft. Hotol can lift loads similar to those carried currently by Ariane, and would provide Europe with the facility it needs both to remain competitive with the US Space Shuttle in the future, and to retain its general capability in space.

The reasons Hotol will be able to operate at a lower cost than Space Shuttle or other conventional launchers, are:

- it uses atmospheric oxygen as fuel during the initial flight phase resulting in a great saving in the all-up weight of the vehicle at take-off. Currently all spacecraft are launched by rocket-powered vehicles using fuels in which the oxygen content can account for as much as 85% of the total fuel weight at take-off. Fuel weight at take-off can be greatly reduced by using a combination of air-breathing and rocket propulsion to provide power. Hotel's air breathing engines drive it to Mach 5 at 26km (85,000ft) altitude before rocket power is required.
- it is unmanned and, therefore, from the engineering point-of-view is a much simpler and less costly vehicle to design and build.
- Hotol is completely reusable having no costly expendable parts such as boosters, or external fuel tanks.

Hotol could be built and operational by the early years of the 21st century. Later versions could carry men into orbit to service space platforms or other equipment in low-Earth orbits. £3 million, contributed equally by the British Government and industry, has been allocated fo fund a proof-of-concept study of Hotol. The study will last up to two years

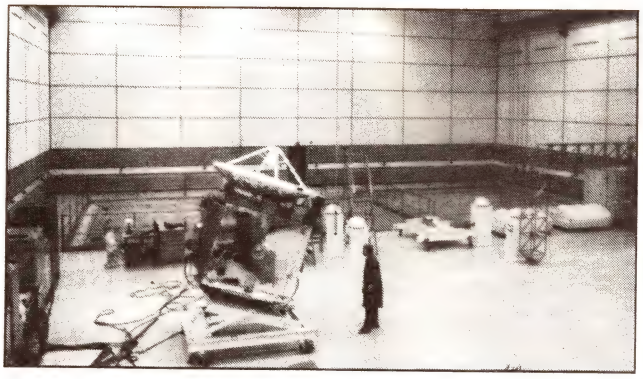


Fig. 10. Spacecraft assembly hall.

Skylark

Skylark is a sounding rocket for space research supplied by BAe. It can carry experiment payloads to alitudes of 1000km and is being used by the West German Space Agency, DFVLR. The first Skylark rocket was launched in 1957. To date 400 have been launched from ranges around the world in various research programmes. One of these is the West German Texus project in which the nature of materials under microgravity conditions is being investigated.

Depending upon the payload carried and the version of Skylark used different space missions can be performed. Payloads from 100kg to 400kg in weight can be carried to altitudes ranging from 150km to 1000km. The useful time available for microgravity experiments can be eight minutes, with significantly longer periods available for extraterrestrial research projects.

Ariane

BAe designed and installed the Ariane hold-down release systems used on the launch platform at Kourou, French Guiana. BAe also supplies a variety of high technology products for Ariane including the auto-pilot electronics unit, solenoid valves, gaiters and carbon-fibre struts for gimballing the engines of the second stage.

A second launch-pad hold-down release system was installed in 1984 for Ariane 3, and a third system has been built ready for the first Ariane 4 mission in 1986. BAe is also building the Spelda structure which will enable Ariane 4 to carry and launch two satellites during the same mission.

Spelda

Spelda (structure porteuse externe pour lancement double Ariane) is part of Ariane 4's payload-bay primary structure. Available in two versions — short (3.78m, 348kg) and long (4.78m, 393kg) — Spelda is a cylindrical structure 3.97m in diameter with a truncated conical upper section. One satellite is carried on a mounting ring fitted to the top of the conical section, and the second satellite is enclosed within the cylindrical portion. After the Ariane 4's nose cone is jettisoned, the top satellite is released then a pyrotechnic line charge splits Spelda in two around its circumference and the upper section is propelled away by a pre-compressed spring system leaving the second satellite free to be released into orbit.

Spelda can accomodate two Class 1 or Class 2 satellites of between 800 and 1400kg mass each.

Spelda is of monocoque sandwich construction comprising an aluminium honeycomb core bonded to multi-layer carbon-fibre skins, with outer glassfibre layers covered with aluminium foil.

BAe designed Spelda and has completed two engineering development models and the first protoflight unit which is to be used on the first Ariane 4 mission scheduled for July 1986. Work has begun on a further five production Speldas required for the initial series of Ariane launchers.

Spacelab shuttle pallets

As a member of the nine-nation Spacelab consortium BAe was responsible for the design and manufacture of Spacelab Shuttle pallets — large structures (height 2.24m, width, 4.35m, length 2.93m) that act as platforms on which unmanned experiments are mounted for carriage in the cargo bays of NSA Space Shuttle Orbiters. Up to 4130kg weight of experimental equipment can be carried on a pallet. Eighteen Spacelab pallets have been manufactured and delivered.

A pallet equipped with five OSTA-1 experiments was carried in the cargo bay of NASA's Orbiter Columbia in November 1981 during the second Space Shuttle mission and another with OSS experiments was carried on the third mission in March 1982. A pallet formed part of the manned Spacelab assembly which was carried into space for the first time in November 1983 abord NASA's Orbiter Columbia. Two pallets were used in the recovery from space of the Palapa and Wester satellites by Space Shuttle Discovery in November 1984, and a three pallet 'train' formed part of the Space Shuttle Challenger Spacelab 2 mission in July 1985.

Half and quarter-length pallets have been designed, and a study has been completed for a proposal to use Spacelab pallets as autonomous general-purpose free-flying spacecraft.

Satellite launch cradles

BAe has built and delivered a reusable cradle for carrying and launching Hughes Leasat military communications satellites directly into space from the cargo bay of a Space Shuttle Orbiter. A Leasat satellite weighs 6000kg at launch. The cradle is a primarily aluminium structure weighing 750kg. It is 2m wide and measures 5m across its open face.

BAe also has the task of designing and supplying reusable support cradles for carrying and launching Intelsat VI series communications satellites from Space Shuttle Orbiters. Intelsat VI satellites weigh 3500kg at launch.

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PHILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA

or

MATHEMATICAL PRINCIPLES OF NATURAL PHILOSOPHY

by

ISAAC NEWTON

1687 — A TERCENTENARY CELEBRATION — 1987

by Dr. T.R. Carson, University of St. Andrews, Department of Physics & Astronomy.

Isaac Newton was born on 25 December 1642 in the manor-house at Woolsthorpe, near Grantham, Lincolnshire. He died on 20 March 1727 at Kensington, London and was buried in Westminster Abbey. Thus he lived under seven monarchs, as well as two protectors, in what can surely be described as an age of revolution. Against this politically turbulent background the world of learning was undergoing, after a similarly turbulent start, its own albeit quieter evolution. The ancient philosophy of Aristotle, despite the efforts of Aquinas, had already sunk into decline. Of the three Philosophies, Metaphysical, Moral and Natural, the latter was poised for its most dramatic development. Man's place in the physical universe had been redefined by Copernicus and Bruno. Bacon and Galileo had initiated a new science, based on observation and mathematically precise description, so immediately exemplified in Kepler's three laws of planetary motion. The most influential philosopher of the seventeenth century was Descartes, whose attempt to construct an all-embracing philosophy of the world, failed even to resolve his own conflict between reason and authority. Nevertheless it had a lasting impact on the future development of natural philosophy through its reduction of all reality to matter and motion. Newton's "Principia" represented the next step along this road. Matter was invested with certain intrinsic properties, both active and passive, while motion became a series of events in space and time subject to quantitative analysis based on premises of cause and effect. Later on the combination of Descartes' analytical geometry and Newton's differential and integral calculus would become powerful tools in forging a complete mechanistic philosophy.

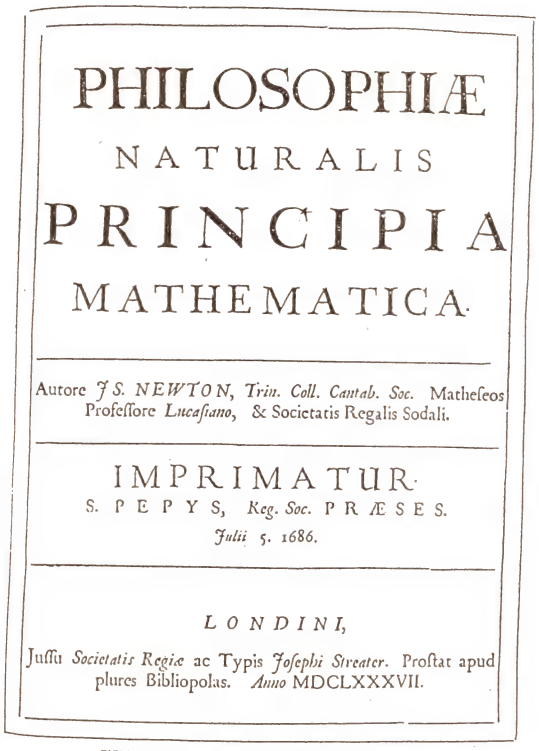
SIR ISAAC NEWTON

Due to the death of his father two months before his birth, Newton spent his early years with his maternal grandmother in Woolsthorpe. In 1654 he entered the grammar school in Grantham, but left in 1656 to help manage the family farm, returning to school in 1660 to prepare for college for he showed a remarkable precocity in mathematics. In 1661 he matriculated at Trinity College, Cambridge, where he became a scholar in 1664 and graduated B.A. in 1665. He became a fellow of Trinity College in 1667 and in 1669 was elected Lucasian professor of mathematics in succession to Isaac Barrow whom he had impressed as "a very ingenious person" and "a man of exceptional ability and remarkable skill". He was elected to fellowship of the Royal Society in 1672 and represented the university in parliament in 1689 and in 1701, and was finally appointed to the post of Warden of the Mint in 1696 and Master in 1699. In 1703 Newton became president of the Royal Society, which office he retained for life. He was knighted by Queen Anne on the occasion of her visit to Cambridge in 1705.

During the years 1665-1666, at a time of enforced absence from Cambridge due to the plague,

at Woolsthorpe, Newton made a number of advances in optics, mathematics, mechanics and gravity. It was mainly with the last three topics that the "Principia" would be later concerned, but it was during this rural retreat that the seeds of that bountiful harvest were sown. Newton himself wrote later "... from Kepler's rule of the periodical times of the planets [Kepler's third law] ... I deduced that the forces which keep the planets in their orbs must be reciprocally as the squares of their distances from the centres about which they revolve: and thereby compared the force requisite to keep the Moon in her orb with the force of gravity at the surface of the earth, and found them answer pretty nearly. All this was in the two plague years of 1665 and 1666... for in those days I was in the prime of my age for invention and minded Mathematics and Philosophy more than at any time since ... between the years 1676 and 1677 I found the proposition that by a centrifugal force reciprocally as the square of the distance a planet must revolve in an ellipse about the centre of force as focus [Kepler's first law]... and with a radius drawn to that centre describe areas proportional to the times [Kepler's second law]". Christian Huygens had already published in 1673 the rule of centrifugal force for uniform circular motion. What Newton did was to define the concepts of quantity of motion (momentum) and force, and the laws relating to them. He also made the conceptual move from centrifugal to centripetal force and generalized from the circle to the ellipse, having already postulated the universality of the gravitational force on the falling terrestrial body and that acting on the Moon and other heavenly bodies. The story of the apple falling from the tree in the garden at Woolsthorpe was told by William Stukely in recounting his conversations with Newton in 1726, and also by Voltaire who obtained it from Newton's step-niece. The tree was cut down in 1820 but a portion of the trunk may be seen in the library of the Royal Astronomical Society in Burlington House, Piccadilly.

The events leading up to the publication of the "Principia" began with the visit to Newton in 1684 of Edmund Halley (soon assistant secretary of the Royal Society and editor of Philosophical Transactions) to pose the question, prompted by a discussion with Robert Hooke and Christopher Wren, as to what orbit a planet would follow if attracted to the Sun by a force varying inversely as the square of the distance. Halley, impressed by Newton's immediate answer, asked for the proof, which Newton sent and was received by Halley with such great satisfaction that he visited Newton again to discuss the matter. He reported to the Royal Society the "curious treatise, De Motu (On Motion)" which Newton had promised to send to the Society. This was received in February 1685, Halley's intention being to secure the position until Newton could publish his work, as he was encouraged to do by Halley and by the Royal Society. In April 1686 the Royal Society received a manuscript, in the hand of namesake and amanuensis Humprey Newton, of what Halley referred to as an "incomparable Treatise on Motion" entitled "Philosophiae Naturalis Principia Mathematica" and dedicated to the Society by Newton. This was in fact the first part of the "Principia", comprising the "Definitions", "Axioms or Laws of Motion" and "Book I — On the Motion of Bodies", bearing the full title of the whole work. The Society resolved to have the manuscript printed without delay at its own expense, and furthermore entrusted Halley to supervise the printing. For financial reasons the Royal Society shortly ordered that Halley print it at his expense which he engaged to do. In June 1686 Newton informed Halley that he had intended the "Principia" to consist of three books, of which the third would concern the system of the world, which he now proposed to suppress because "Philosophy is such an impertinently litigious Lady that a man had as good be engaged in Law suits as have to do with her". Newton realized that the title of the whole work would no longer be as appropriate, considered changing it, but on second thoughts retained the former title to help the sale of the book. Halley begged Newton "not to...deprive us of your third



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J S. NEWTON, Trin. Coll. Cantab. Soc.* Matheſeos Profeſſore *Lucaſiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater.* Proſtat apud plures Bibliopolas. *Anno* MDCLXXXVII.

TITLE PAGE OF THE FIRST EDITION OF THE PRINCIPIA

ILLUSTRISSIMÆ
SOCIETATI REGALI
a Sereniſſimo
REGE CAROLO II
AD
PHILOSOPHIAM PROMOVENDAM
FUNDATÆ,
ET AUSPICIIS
POTENTISSIMI MONARCHÆ
JACOBI II
FLORENTI.

Tractatum hunc humillime *D. D. D.*
J S. NEWTON.

book", adding that it would make the "Principia" acceptable to "those that will call themselves philosophers without mathematics, which are by far the greater number". Newton deferred to Halley and duly delivered to him "Book II — On the Motion of Bodies in Resisting Media" in March 1687 and "Book III — On the System of the World" in April 1687. On 5 July 1687 Halley wrote to Newton that he had "at length brought your book to an end, and hope it will please you". Halley had written a latin ode, dedicated to Newton, with which he prefaced the work. In his own preface Newton paid a glowing tribute to the assistance which Halley had given him. The title page bore the "imprimatur" of Samuel Pepys, President of the Royal Society. The number of copies printed is unknown but has been estimated as high as four hundred. Newton received twenty for himself and forty for disposal through booksellers. The price to the trade was six shillings in sheets, reduced to five shillings for cash, but nine shillings leatherbound and lettered!

News, emanating from Halley and John' Flamsteed (first Astronomer Royal), of the impending appearance of the "Principia" had generated much excitement. Reactions to the book were quick to follow publication. Two reviews appeared in French (Journal des Scavants, Bibliotheque Universelle) the latter being attributed to John Locke, one in Latin (Acta Eruditorum), and one in English (Philosophical Transactions) by Halley. Readers were left in no doubt as to the scope and scale of Newton's achievement. Newton's work appealed particularly to mathematicians like James Gregory (St Andrews and Edinburgh) and his nephew David Gregory (Edinburgh and Oxford). Perhaps the first continental student of Newton was Nicolas Fatio de Duillier, a Genevese mathematician who was instrumental in spreading news of the "Principia" to Huygens in Holland and to Leibnitz, otherwise known for his controversy with Newton regarding the calculus, in Germany. An early casualty was Descartes' philosophy, particularly as it applied to mechanics, including his theory of vortices relating to celestial motions. However, to Newton the concept of action at a distance without mediation was an absurdity, a point of some importance when considering the later revolution due to Einstein. Newton also made it clear that while invoking gravity as a cause of (change of) motion, he was making no statement regarding the cause of gravity itself and permitted himself but one reference to God in the first edition. Richard Bentley, Master of Trinity College, in his Robert Boyle Lectures (1692), noted that the dispositions of the planets relative to the Sun were critical for the sustenance of life thereon, leading him to "discern the tokens of Wisdom in the placing of our Earth". George Berkeley, Bishop of Cloyne, attacked Newton's concepts of absolute space, absolute time and absolute motion as inadmissible since they entertained "something besides God which is eternal, uncreated, infinite, indivisible, unmutable". Joseph Addison too upheld the thinking of Descartes, although both Berkeley and Addison would later publish defences of the Newtonian philosophy. Leibnitz considered that gravity "without any mechanism... or by a law of God... without using any intelligible means, ... a senseless occult quality...". Roger Cotes (first Plumian Professor of Astronomy), editor of the second edition (1713) of "Principia" under Bentley's supervision, advised Newton to counter the criticism of Leibnitz. For the second edition Newton thus prepared the famous General Scholium containing the sentence "...And thus much concerning God: to discuss of whom from the appearance of things, does certainly belong to Natural Philosophy...". Herein too is found the famous declaration "...hypotheses non fingo... (I frame no hypotheses)", which must be taken only in the context of the cause of gravity, for Newton framed many hypotheses. The third edition (1726) was prepared for Newton by Henry Pemberton who also, a week after Newton's death, announced a translation of the "Principia". This was never published and the first English translation was that of Andrew Motte in 1729. Fatio was the author of the epigram on Newton's tomb: "Sibi gratulentur Mortales, Tale tantumque extitisse Humani Generis Decus (Let mortals rejoice that there has existed such and so great an ornament of the human race)". Amongst the many tributes that have been accorded Newton's "magnum opus" few are as generous as that of Laplace in referring to the causes "which will always assure the "Principia" a preeminence above all the other productions of the human intellect".

Solar arrays

For the past 20 years, BAe has built solar arrays and deployment mechanisms for a number of spacecraft. These have included the Ariel 3, 4 and 6, X-3 (Prospero) and X-4 (Miranda), and Cos-B scientific satellites. Twelve solar array sets were provided for Intelsat IV and IVA communications satellites, and four sets for the American Comstar satellites.

More recently, BAe has been developing the flexible roll-out arrays having a total area of 60sq m for the NASA/ESA Hubble Space Telescope. Each wing of this array measures 11.82m (span) by 2.83m. The complete array comprising some 48,760 silicon solar cells, weighs 160kg and generates 6kW at the beginning of its life in orbit.

The arrays are unreeled from drums and deployed automatically either side of Space Telescope. A duplicate drive and duplicate wiring is provided. Provision has also been made for the arrays to be unrolled manually by astronauts using special tools. The arrays can be deployed and retracted independently and also replaced in space, the dismounted arrays being returned to Earth for refurbishment.

Spacecraft assembly hall

In 1984 a new spacecraft assembly hall was completed. This new facility was established to enable the larger satellites now being developed to be assembled at Stevenage. At any one time as many as four satellites can be under construction in the hall. Satellites currently being assembled there include the Olympus-1 large multi-role communications satellite for ESA, and Skynet 4 military communiations satellites for the UK Ministry of Defence.

The assembly hall is a windowless building 27m (88ft) long, 27m (88ft wide) and 11m (36ft) high. It has two hydraulicallypowered platforms, each 7.5m (25ft) square, which can be lowered 4.5m (14ft) below floor level permitting satellites over 12m (40ft) tall to be built. Class 100,000 cleanliness conditions prevail, and the temperature is maintained at 20 °C ± 1 °C with relative humidity at 45% ± 5%. The steelframed building provides limited electromagnetic protection and the floor is electrically conductive to prevent residual electric charges accumulating. Electromagnetic compatibility tests can be conducted on satellites in the hall. In an adjacent room are four computer-controlled checkout stations used for testing satellites and their equiment at various stages in their construction.

Spacecraft equipment

BAe has built power-conditioning equipment for more than 30 satellites, stabilisation systems for both spinning and three-axis stabilised satellites, and has developed and tested reaction and momentum attitude control wheels. BAe supplies a range of solar array drive units capable of supporting producing up to 6kW per drive unit.

Instrumentation sensors produced include sun sensors orientating solar arrays; a sensor for detecting microwave emissions from sea surfaces; and an infra-red radiometer which was installed aboard the American Nimbus 7 advanced atmospheric research satellite to monitor energy output from the Earth's upper atmosphere.

Utilizing the hardened version of the Texas Instruments SBP 9989 microprocessor, BAe has built a spacecraft microcomputer module (SMM) for general use in satellite systems requiring data processing services. Up to 64 SMMs can be linked together, if required. Software needed to control the operations of SMMs is available. The SBP 9989 was selected as it is bipolar I^2L device resistant to radiation damage.

BACKGROUND TO HOLLOW EMITTER TECHNOLOGY

by Sue Cain and Ray Ambrose*

Hollow emitter technology falls into the area of power transistor technology lying between bipolar and power mos, providing an economic solution to high voltage switching. Ideally suited to switching frequencies which cause problems to both bipolar and power mos devices, hollow emitter technology improves the performance of multiepitaxial mesa power transistors. This article describes the features of hollow emitter technology, and discusses the characteristics of some currently available devices.

Within the field of power transistor technology, the area between bipolar and power mos is occupied by high voltage switching. An economic solution is provided by hollow emitter technology.

Hollow emitter technology is ideally suited to switching frequencies which cause problems to bipolar and power mos devices. Products such as SGS's Fastswitch range provide rugged operation at very high switching speeds, and high levels of efficiency which allow more compact designs with smaller heatsinks.

When compared to industry standard high voltage devices, hollow emitter types provide faster switching times and a lower saturation voltage. The term 'hollow emitter' refers to the missing centre region in the emitter area, which reduces the charge crowding effect at this point, as well as the storage time required to remove the excess charge.

A thinner intermediate N layer, present with hollow emitter devices, reduces the collector resistivity and the saturation voltage.

Standard versus hollow emitter technology

Hollow emitter technology has developed out of the standard high voltage multiepitaxial mesa technology, the main difference being that, with the new technology, the emitter is not diffused over the normal area but only on the normal emitter edge.

This difference has been implemented to overcome the charge-crowding effect in the centre of the emitter during the off transition found in industry-standard high voltage devices. The result is much faster switching times.

Standard high voltage

During the ON transition, the charge in any normal high voltage device is easily built up on the edge of the emitter. At the same time, the increase in base resistance towards the centre of the emitter reduces the charge level at the device's centre.

While undergoing the OFF transition, the base extraction current of the device can rapidly eliminate the charge at the edge of the emitter, but the charge at the centre is removed with some difficulty owing to the transversely distributed resistance in the base under the emitter finger.

While the edge is turned off, an amount of charge remains at the centre of the emitter diffusion which deceletates turn-off time. These conditions are illustrated at Figures 2a and 2b.

Hollow emitter

In the case of transistors such as the SGS Fastswitch range, diffusion at the centre of the emitter is prevented by masking, as appropriate. The resulting hollow in the emitter prevents the accumulation of charges that would slow down the turn-off time.

Removal of the central region, with consequent reduction of the emitter area has a negligible effect on V_{CEsat}. There are two reasons for this: first, the centre region of the standard device carries less charge, and second, the intermediate N layer is thinner, reducing the resistivity of the collector, producing a fast switching, highly efficient device.

Comparison of switching times

Comparison of a standard multiepitaxial mesa device with a hollow emitter device of the

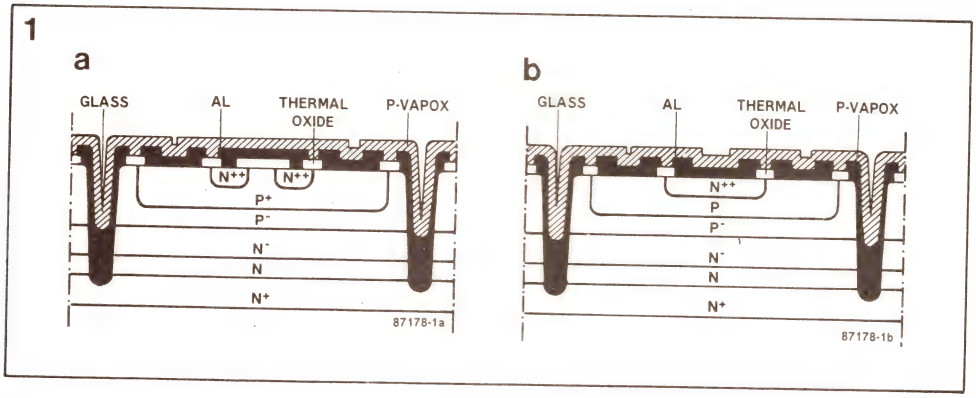


Fig. 1 Structure of the hollow emitter technology (a) and the standard multiepitaxial mesa technology (b).

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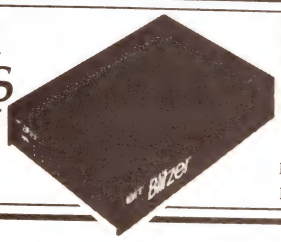

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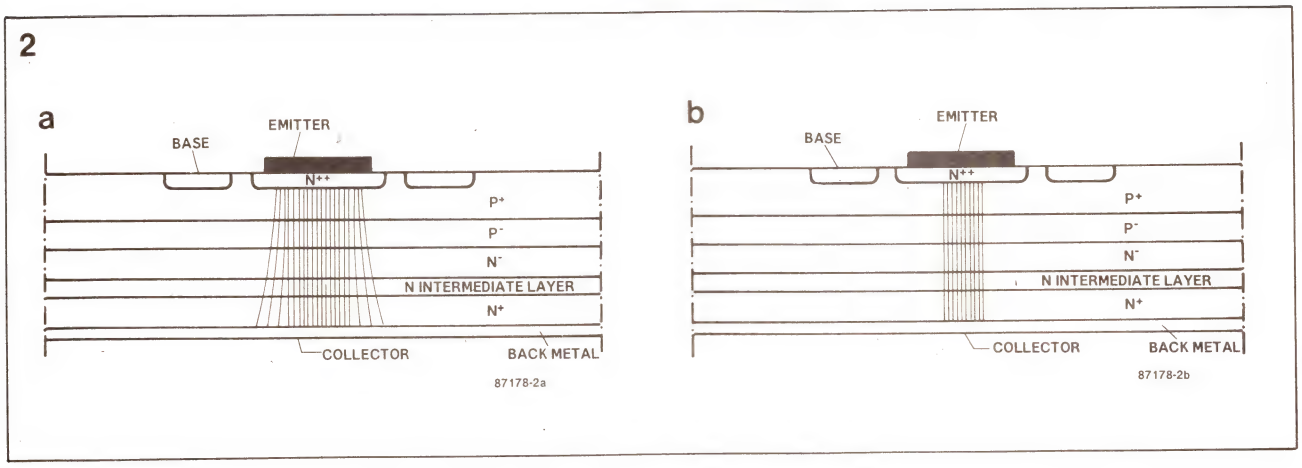

Fig. 2 Charge condition during conduction — normal high voltage technology.

Fig. 2b. Charge remaining after turn-off.

same dimensions and similar static characteristics gives a clear indication of the advantages provided by the latter. The fall time of the hollow emitter device is clearly superior to that of the standard device, while storage time is also slightly better. Figure 3 compares the switching characteristic curves for two typical devices, the BUX48 standard multiepitaxial mesa device, and the SGSD00032 hollow emitter, showing that with resistive loads the results produced by the hollow emitter are better than those for the standard device over a wide range of collector current.

Shorter fall and storage times automatically give rise to reduced dissipation energy while the device is turned off. Furthermore, both base and emitter switching times are almost always equally low in the case of hollow emitter devices. For example, the SGSD00035 t_{fall} is 50ns for both switching conditions.

Reverse bias safe operating area (RBSOA)

Figure 4 compares two comparable devices, from the standard and the hollow emitter technologies, comparing their reverse bias safe operating areas. Although the RBSOA characteristic curves are better for the standard device at 400V, the hollow emitter device has been optimised to give an improved RBSOA at higher voltages to suit switch mode power supply applications.

It can be readily demonstrated that the hollow emitter device gives more protection at higher voltages, and this is balanced by adequate protection in areas of lower voltage and high current.

Applications

Hollow emitter technology has been devised in order to produce devices with extremely short switching times as regards their high voltage and current capabilities. As a result, hollow emitter devices are highly efficient, and are therefore well suited for applications demanding fast switching without high energy consumption.

Typical applications are those which require the use of inverters, switching regulators, fluorescent lighting and deflection circuits with high definition displays.

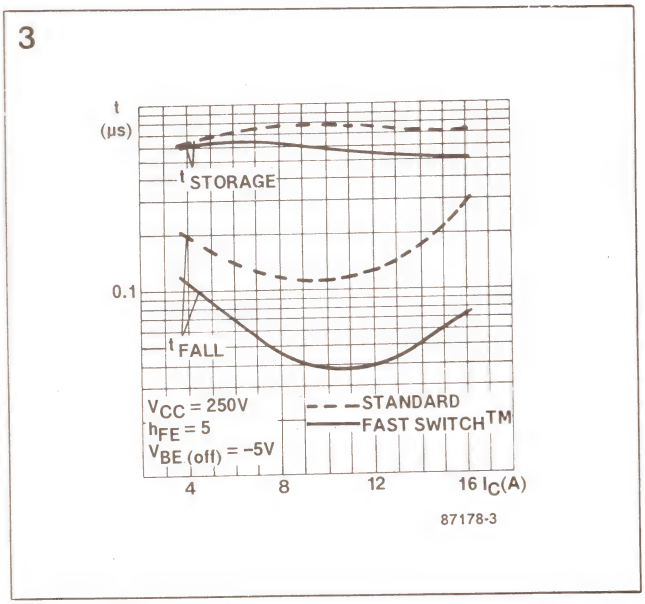

Fig. 3. Storage and fall times for standard and high voltage types.

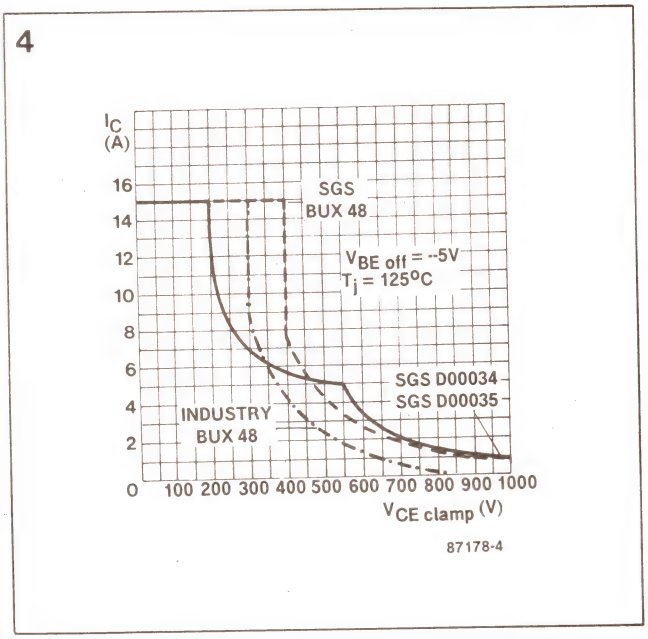

Fig. 4. Reverse bias safe operating areas for standard and hollow emitter types.

*Sue Cain is with BA Electronics and Ray Ambrose with SGS

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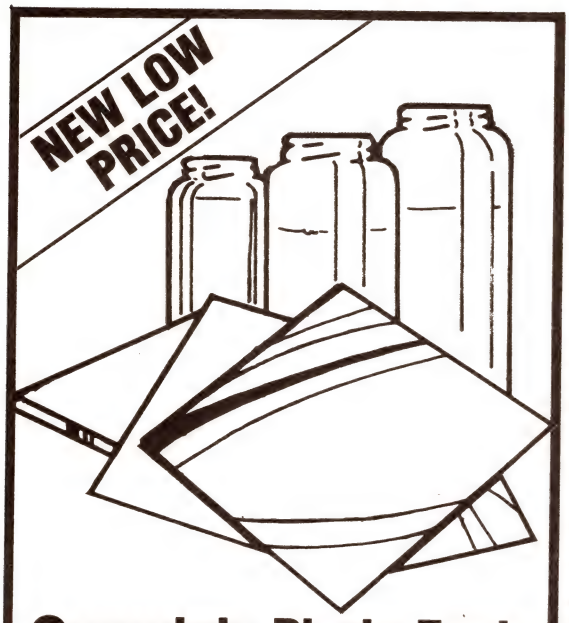

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Pro quality frame makes negs or pos up to 225 x 300mm, from film pattern or even direct from printed magazine pages. Contains spring loaded steel exposing frame with glass, backboard, yellow filter & instructions. Cat N-5710

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215 x 295mm yellow filter for exposing Datak light-sensitive products to pcb patterns. Full instructions included with master kit.
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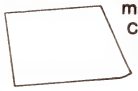

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Sure beats using the old ball-point pen! Professional quality results demand a professional approach. Aluminium ball one end, flat pastic the other. Cat N-5715 $10.45

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Bonanza in electrolytics for bargain hunters

If you're in the market for electrolytic capacitors at present – you're in luck, because a number of retailers are currently offering good bargains in a wide variety of common and uncommon values and voltages.

Ritronics from Melbourne are importing a range of large value, small size pc mount and axial (pigtail) electrolytics under their own brand of Ritron. They are ideal for power supplies and single board power amp modules, according to proprietor, Rod Irving.

The Ritron range in pc mount types include 2500 uF/63 V, 2500 uF/80 V and 5600 uF/40 V. The axial types include the popular 4700 uF/25 V value. These are all around 25-30% smaller than the same values in commonly stocked lines.

If you're currently assembling a precision 50 V power supply or a hi-fi amp and are looking for a top quality, long-life electrolytic, then check out Jaycar's current special on 6800 uF/63 V can-type electros made by German manufacturer, Roederstein. At $7.50 each, they'd be the bargain of a lifetime!

For those assembling one of the 6000-series stereo power amps, palaver with Pre-Pak for your requirements in 8000 uF/75 V can-type electros for the power supply. They're $8.00 each and measure 34 x 85 mm (cat. no. 18-3500).

Looking for bargains in "computer grade" electros? Well, at present, there's a bit of a price war going on between two Sydney retailers – Pre-Pak and Sheridan. For a 100,000 uF/10 V can – try Pre-Pak at $6.00, Sheridan at $9.00. But Sheridan have 10,000 uF/40 V Sprague caps for $6.50 while Pre-Pak have 10,000 uF/16 V caps at $6.00. Count on a visit to both Lewisham (Pre-Pak) and Redfern (Sheridan).

MAX chips

Did we start something? Ever since we published the data sheets for the Maxim MAX231 and MAX232 RS232 line driver ICs and included them in a couple of projects, there's been a rash of retailers falling over themselves to stock these handy little devices.

First cab off the rank was that wily old fox, well, wily anyway – Geoff Wood. He's able to supply both types, although local stocks of the MAX231 are at times "thin". Rationing may be in vogue.

Jaycar are stocking the MAX232 and Ritronics has just added it to their standard stock lines.

Eagle Electronics in Adelaide now stock the MAX232 and you might also try them for the MAX231. Force Electronics, also of Adelaide, joined the ranks of MAX suppliers just before Christmas, too.

Now the bulls have turned into bears on the bourse, and Uncle Joh has seen the light (likely reflected from the daggers in the cabinet room) we might see that old retail conservatism replaced by some adventurous risk-taking behind the counter. Could be fun!

We'll keep you posted.

Balltearer buffer bargain!

After a bargain in digital devices? Then you could hardly go wrong with Geoff Wood's current offering of the CD4503 hex tri-state buffer for a ludicrously low thirty five ¢!

Just the thing for microprocessor and other digital projects, the 4503 is widely used so you'd be well advised to keep a few on the shelf for spares as well as a handful for mucking about on the bench.

The 4503 is also known as the 80C97. Contact **Geoff Wood Electronics, 229 Burns Bay Rd (PO Box 671) Lane Cove NSW 2066. (02)427 1676.**

LCD dot matrix displays

Sheridan Electronics of Sydney has limited stocks of Hitachi LCD dot matrix displays, complete with drivers.

Models in the range include the H2532A 16 column at $35.00, the H2535 32 column at $40.00, the H2538A 40 column at $80.00 and the H2539 80 column at $85.00.

These prices represent a considerable saving over the original manufacturer's price and the alpha-numeric displays are ideal for all sorts of applications where low voltage and low power consumption are required.

For further information, contact **Sheridan Electronics, 164-166 Redfern Street, Redfern 2016 NSW. (02)699 5922.**

VALE NEVILLE FROLLEY

It is with some sadness we honour the passing of one of the electronics retail industry's 'identities', Neville Frolley of All Electronic Components in Melbourne.

Neville purchased the long-standing Melbourne retailer then known as E.D. & E. Sales in 1974, having been previously Service Manager at Kodak. With the support of his family, he built the business on two solid foundations: offering the widest possible range of kits and components and giving personal service to both counter customers and mail order customers alike. Indeed, All Electronic Components established an inventory in kits not emulated by any other firm in the country, carrying printed circuit boards for every project published by the major electronics magazines in Australia.

In late 1986, Neville was diagnosed as having cancer and underwent an operation which was pronounced a success. However, in mid-1987 the cancer was found to have returned and Neville passed away on October 16.

I knew Neville since the late 1970s and always found him personable, scrupulously ethical and willing to give generously of any assistance he could offer. The success of many major projects was entirely due to his extensive efforts to source essential, but uncommon, items in componentry and hardware.

Neville's eldest son Andrew has been managing the business for the past few years and will continue the All Electronic Components' tradition of giving personal service and offering the widest possible range of kits, components and printed circuit boards.

– Roger Harrison

PROJECT BUYERS GUIDE

The Profile 4 loudspeaker, as detailed in the article, is distributed by Scan Audio of Melbourne and kits are available from dealers around the country. Audition a built-up pair by all means, but take your cheque book/credit card with you!

The Stand-Alone Morse/RTTY Decoder is available through Dick Smith stores around the country for a little under $140. Check your local Dick Smith store or dealer for availability. They can also supply shortwave receivers and printers if you're starting from scratch!

The AEM4511 MIDI Interface should present few problems to constructors. The preferred UART, the Standard Microsystems COM8017, is distributed by Total Electronics. Try Jaycar stores or Active Wholesale in Melbourne, who were reported to have them in recent months, or Geoff Wood Electronics in Sydney. The General Instruments AY-3-1015D is distributed by RIFA and has been available through stores such as Ritronics in Melbourne, Jaycar and Geoff Wood.

The AEM4000 SuperMicro will soon be available as a kit from Maestro Distributors and sold through a special offer to AEM readers. Stay tuned!

The Multi-Function Counter in our Elektor section this month is based on the Intersil ICM7226, distributed in Australia through R&D Electronics. It's not a commonly stocked item, but retailers stocking Intersil devices may have it or obtain it for you. Try Geoff Wood Electronics in Sydney, Radio Spares in the capitals and Radio Parts in Melbourne.

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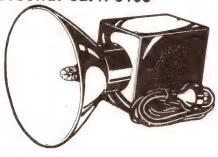

Look Mum. No bike!

The ultimate in protection ! One of the best alarms around. Includes its own siren output. Cat K-3252

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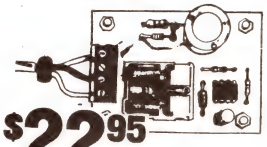
Add an Ignition Killer for Protection



Nothing's worse than a car that misbehaves. Especially if you're trying to knock it off. Imagine, starts, but very soon splutters and stops. Bill Sykes thinks the car's crook and goes off searching for another! You return to your car, reset the ignition killer — and drive away! Cat K-3255

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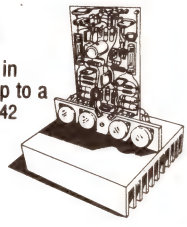
100W Amp Module



Use two for stereo, or even use in bridge for double output! (Get up to a massive 200W output!) Cat K-3442

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Build an amplifier: economically!

Here's a great first "big" project. When you've finished mucking around, build an amplifier! It's not too difficult — our new Economy Amplifier Kit makes it a cinch! Kit is "short form" — does not include case (H-2900) or transformer (M-6672). Over 8W per channel at <0.05% distortion, CD, tuner, disc and aux inputs. Cat K-4001

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Flasher

Make it as the latest in electronic jewellery, or a burglar warning light, etc. The choice is yours and it's easy! Cat K-2621

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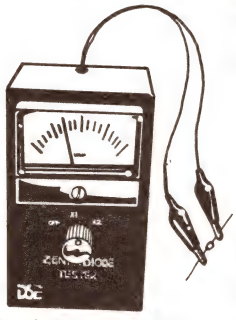
FunWay One Project Packs

Two project packs to allow you to build any of the kits. Project Pack One allows you to build any of the first ten kits in FunWay One. Project Pack Two gives you the additional components required to build any of the 20 kits (needs Pack One too!) Note — FunWay One book is NOT included with these kits. FunWay One: Project Pack One Cat K-2600

$8.95

How do you test a Zener?



Let's see. Out with the power supply. Work out the series resistor. Get the voltmeter and put it across the zener. Turn on the supply. Woops! Wrong resistor. One cooker Zener... Or you can build the Zener Diode Tester. Very simply and accurately checks Zeners without danger. Especially handy in the service lab when the markings are worn off! Cat K-3051

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IR Remote Control Preamp

Full command over your hi-fi system without moving from your chair! The IR Remote Preamp comprises a complete preamp in which all functions can be selected by infra red remote control. And it's loaded with features! Cat K-4003

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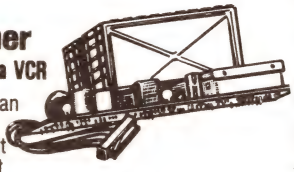
Teletext Tuner

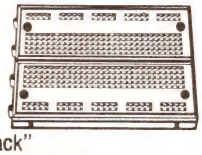
Teletext — without a VCR



The Teletext Tuner can be built into your Teletext Decoder (Cat K-6315) so you don't need to own a VCR. Kit comes complete with everything you'll need including comprehensive, easy to follow instructions. Cat K-6319

$99.95

Mini Project Board



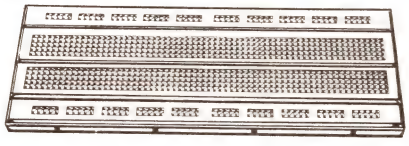
80 x 60 x 8mm board with 58 groups of 5 connected terminal points. Grid is laid out in alpha-numeric format for simple "track" identification, and the board is supplied with a pad of overlays so you can mark out circuitry for later use or for transferring to pcb/matrix board. Cat P-4614

$11.55

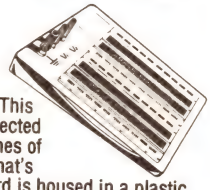
Giant Project Board

Similar to above, but this one has a whopping 128 groups of terminal points. Overall board size 178 x 67 x 8mm, also has 8 bus lines of 25 connected terminals. Dependable corrosion-free terminals for long life and circuit reliability. Cat P-4615

WAS $18.95 **NOW $17.95**



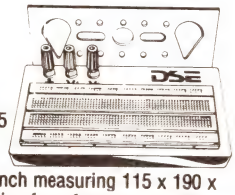
Project Boards PLUS!



A complete mini work bench! This one has 256 groups of 5 connected terminal points plus 16 bus lines of 25 connected terminals. But that's not all: the 130 x 170mm board is housed in a plastic "work bench" complete with three terminals (for power connection, input/output, etc). Overall size is 150 x 225 x 20mm. **Bonus:** Work pad included for circuit working. Cat P-4616

$26.95

And one with a panel!



128 groups of five terminal points plus 8 bus lines of 25 points in a protoboard measuring 173 x 65 x 8mm. Housed in a plastic work bench measuring 115 x 190 x 15mm, complete with provision for a front panel with holes for pots, switches, even TO-3 transistors! Three terminals are also included for connection. Cat P-4617

$20.95

100W HF Linear Amplifier

Designed for our HF Transceiver (K-6330) but also perfect for use with a huge range of QRP commercial gear, in the range of 3 to 15 watts output. Gives around 10 to 14dB gain so up 100W output could be obtained from a very modest input. Cat K-6331

$379

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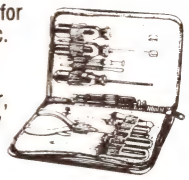
Computer Tool Kit!

A 12 piece computer tool kit for those repairs, alterations, etc. With IC inserter/remover pin straightener, screwdrivers, reversible torque screwdriver, pliers and more. All in handy zippered case! Cat T-4839



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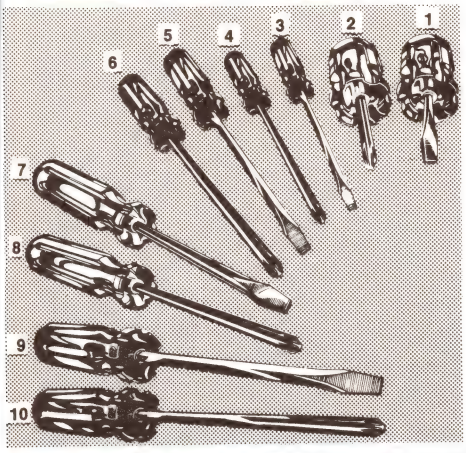

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Build the "Profile 4", a top-quality 4-way loudspeaker

Tom Manning
Scan Audio Pty Ltd

This build-it-yourself speaker delivers top performance from a 4-way bass reflex design, featuring a frequency response flat within ±4 dB from 40 Hz to 25 kHz, excellent transient response and dynamic range plus low distortion.

OVER THE LAST FIVE years we have seen a large increase in the number of high quality, fully imported loudspeakers available in Australia. Unfortunately, the cost of these speakers is also rising, due mainly to increasing labour costs worldwide coupled with our falling dollar. This situation is forcing many hi-fi buyers to accept performance much below the desired standard.

It is for these reasons that Scan Audio has released a range of high quality build-it-yourself loudspeaker kits employing Danish manufactured Dynaudio drive units. The largest of the three systems in the range, the Profile 4, is discussed here.

The name Dynaudio is not currently well known amongst Australian audiophiles. However, this small Danish company has been manufacturing and exporting loudspeaker drive units of high quality since 1968. An innovative company, it pioneered the use of ferro-fluid cooling, "hexacoil" voice coil techniques and the "phase homogeneous" area cone (on which there will be more later).

Project background and design philosophy

The conventional dynamic loudspeaker design employing two or more moving coil drivers has endured for many years, and for a number of good reasons. It is reliable – cone/dome drivers being less susceptible to damage from abuse than electrostatic planar types, it has predictable bass end performance when cabinet design and woofer performance are considered as a system and it still remains the most efficient means of converting the amplifier's signal into useful acoustic energy. Additionally, it is compact and once a system design has been finalised, is relatively easily constructed by the home builder with fairly simple tools.

It is these reasons, particularly the last, which has prompted us to design a no compromise "box speaker" using componentry sourced from the best manufacturers and possessing the following qualities:

- Outstanding bass reproduction characterised by lower limit frequency and transient response.
- Midrange and treble reproduction with outstanding definition, linearity and transient response plus an even radiation pattern in the mid-range.

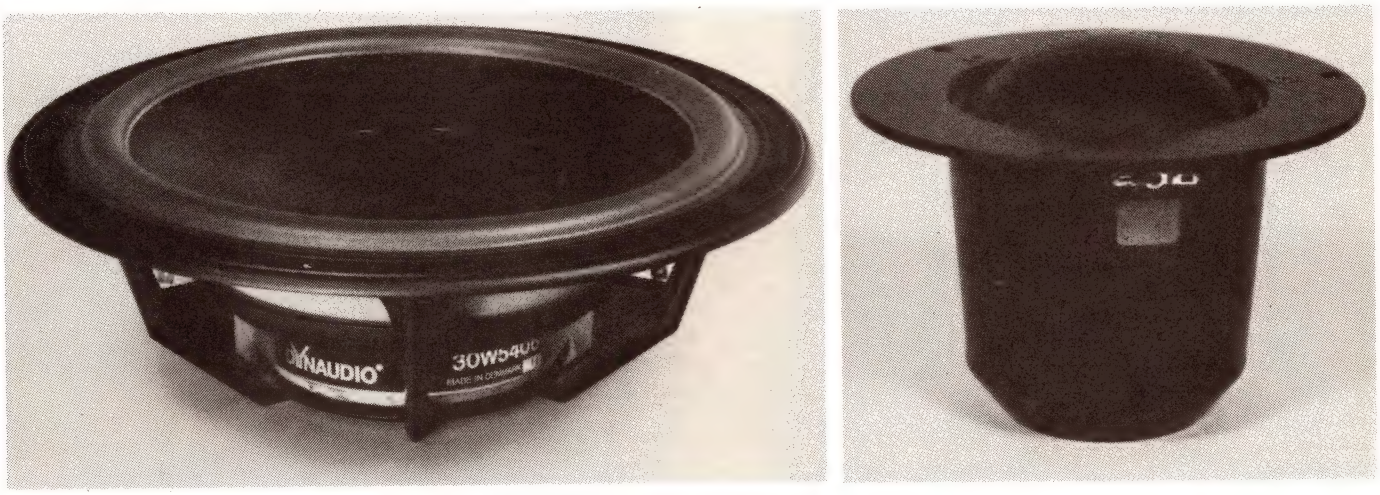
The finished loudspeakers. Note that the mid-range driver and two tweeters are aligned to the left side of the cabinet on the right hand speaker here, which is the right speaker. The left speaker has the mid-range driver and tweeters placed on the right side of the cabinet. The boxes are available finished in light oak (as shown here), walnut, jarrah and black (other finishes are available to order).

- Realistic stereo imaging with the ability of the speaker to place instruments solidly in the sound stage with a true sense of depth and spaciousness.
- Precise, even dynamic range throughout the speaker's frequency range.

In our experience, it is these qualities more than any other, which determine the ultimate musicality of any audio component.

Bass driver and box design

A bass speaker of this cost and quality should be expected to give reproduction of the highest standard and for this reason, much consideration was given to model analysis using theory first documented by the now famous Australian engineer,



The Dynaudio 30W54 bass driver, left, and the D76AF dome mid-range, right.

Neville Thiele, and later expanded by another Australian engineer, Richard Small. Thiele and Small showed that the low frequency performance of a speaker could be accurately predicted once the values of certain factors were known. These factors are now known world-wide as Thiele-Small parameters and are as follows:

1. The free air resonance (Fo), which is the frequency at which the moving system of the driver exhibits the maximum output for the minimum electrical signal.

2. The total Q factor of the driver (Qt), which is the quality factor at resonance and which indicates the combined effects of the drivers electrical and mechanical damping of the moving system at it's free air resonance.

3. The VAS, which is the volume of air in litres needed to provide the same restoring force to the cone as does the suspension. Expressed more generally, an indication of the "springiness" of the suspension system.

When these factors are known, it becomes possible to model low frequency performance extremely accurately.

The woofer specified for the Profile 4 is the Dynaudio 30W54, a 300 mm driver of extremely rugged construction. A look at the cutout construction of the driver in the accompanying picture shows the rigid magnesium alloy frame, shallow cone profile and long throw suspension. It is no surprise that the Thiele-Small parameters of this driver make it ideal for a standard alignment (the matching of driver to cabinet). In fact, it fits an alignment designated "B4" by Thiele. The B stands for Butterworth, a well known response used widely in filter design, and the 4 indicates that the response is a fourth order type meaning that the output will fall by 24 dB per octave below the system resonance.

A study of the comprehensive data provided by Dynaudio, indicates that the optimum cabinet volume would be 120 litres. A large cabinet by today's conventions, but necessary if true, deep and clean bass is desired. A look at the impedance of the system, Figure 6, shows the maximum vent output to be 28 Hz. The dip in impedance at this frequency is caused by the vent output being 180 degrees out of phase with the driver's radiation, resulting in "back loading" of the cone at this frequency.

Not only does the vented box give us an increase in useable bass output, but when compared to the totally enclosed box, the power handling at this frequency is also greatly increased. A large driver such as this has many advantages over smaller types, but this is paid for by its increasing directiveness at higher frequencies. As the dimensions of the cone become wavelength related, the radiation will be narrower in both the vertical and the horizontal planes, causing beaming effects. To overcome this, we have chosen a crossover point of 300 Hz, well below this troublesome area, enabling us to use this driver purely in the "piston operating" mode.

Midrange driver

A study of the table showing the average distribution of energy in music will reveal the enormous midrange content of most musical instruments and vocal types. The human ear is particularly sensitive to anomalies in the region between 400 Hz and 1 kHz and for this reason any multi-way speaker system must have at its heart a midrange driver capable of covering this region without the disturbance of a crossover point and its accompanying amplitude and time (or phase) distortions.

Dynaudio manufacture four different midrange drivers, the specification of each making it suitable for a particular application. The "creme de la creme" is the D76AF dome unit which is a 76 mm dome driver of remarkable design. Initial tests showed the smaller dome drivers in the range to have some promise, but the smaller moving mass of these units results in a higher resonant frequency and reduced excursion capabilities, thus necessitating a crossover point in the critical region somewhere around 600 to 700 Hz.

The lightweight moving assembly of the smaller units does however make for smoother reproduction in the higher frequencies between 1 kHz and 4 kHz. Faced with the first of several inevitable trade-offs, we opted for the D76, believing that the benefits of smooth response in the lower mid-range would outweigh the slight roughness in the higher regions as this could be easily corrected by the strategic placement of a crossover point.

The heart of the D76 is a magnet system of unusual construction. Dynaudio call it the "centre magnet system" and it is illustrated in Figure 2 which you can compare with a conventional dome driver system shown in Figure 1. Instead of the conventional arrangement with the centre pole piece being coupled to the underside of the magnet and the top plate forming the opposite pole of the magnetic circuit, the centre magnet system concentrates the magnetic field in the voice coil gap by positioning the magnet structure inside the voice coil and directing the magnetic flux around the magnet where it is more densely concentrated on the voice coil.

According to Dynaudio, this system maintains even flux at ▷

all excursion levels, resulting in a reduction of distortion of more than 10 dB. In addition, it reduces the Qt of the driver, facilitating the use of first order crossover filters. This driver also uses a progressively damped rear chamber, hexacoil voice coil construction and soft roll-off suspension. Because of its low Qt and Fo, it was seen as an ideal choice for a system of this type.

Treble system

The relatively large construction of the D76 limits its useful response to about 3 kHz and it was thus necessary to choose a tweeter capable of performing well down into this region. The long voice coil excursion necessary for a tweeter operating at 3 kHz with a first order filter pointed to the Dynaudio D28AF as a good choice. The D28AF has a dome/voice coil assembly light enough to provide good high frequency response up to 15 kHz, yet large enough to handle high power at 1.5 kHz where the voltage on the driver will be only 6 dB down relative to the crossover point.

Once again we are faced with a design trade-off, but one that is easily rectified. Any moving system suffers from mass reactance, which means that the inertia of a device with both mass and compliance becomes dominant at a certain frequency.

In the case of the D28AF, the response dies a natural death at around 15 kHz. To extend the response of the system to well beyond 20 kHz (35 kHz in fact!), we chose to use the Dynaudio D21AF super tweeter. This unit is similar in construction to the D28AF, but with a moving mass of only 0.24 gram. A glance at the crossover shows that the D28AF has no low pass attenuation (as does the D21AF). Both tweeters are functioning in parallel – the D21AF being fed through a high pass network consisting of a 1 uF capacitor.

Crossover construction

As mentioned earlier, this circuit is a first order design and is extremely simple. We are sure that many of you will disagree with our choice of filter slopes, but the onus of proof of the superiority of higher order networks lies with you! The main criticisms of first order crossovers seem to be that they are unable to provide adequate signal attenuation outside the driver's pass band. As previously mentioned, by carefully choosing wide bandwidth drivers of suitable construction, this problem can be eliminated completely.

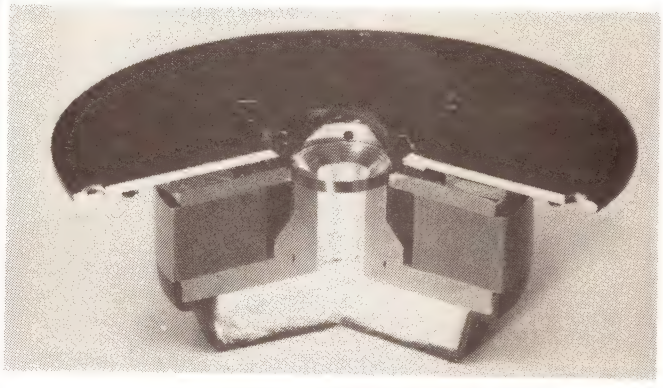
All dynaudio drivers are ruggedly constructed, making them ideal for use with first order crossovers. After evaluating the performance of countless different speaker systems, we are convinced that the 6 dB per octave design is the only type capable of preserving the natural transients and harmonic structure present in today's high quality recordings.

An explanation of the circuit is as follows: L1 is the low pass section for the woofer with the upper rolloff (3 dB down) frequency being at 300 Hz. The series R-C network across the woofer's terminals possesses a decreasing impedance characteristic with increasing frequency, thus compensating for the rise in impedance of the woofer at the region where voice coil inductance becomes significant.

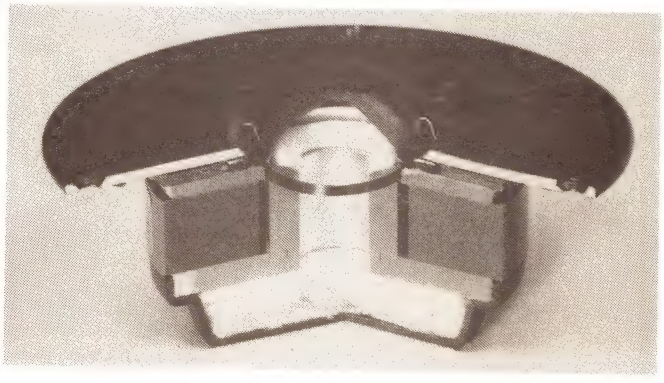
The mid-range driver is fitted with a bandpass circuit comprised of L2 and C2, with the rollof (3 dB down) frequencies placed at 300 Hz and 3 kHz. The resistor R2 provides a degree of attenuation (about 2 dB) to compensate for this driver's extra sensitivity compared to the others, while R3 keeps the impedance constant.

The treble section consists of C3 as a high pass filter, with R4 providing about 1.5 to 2 dB of attenuation. This section is 3 dB down at 3 kHz. The D21AF super tweeter, as discussed earlier, is designed to crossover at about 15 kHz and no attenuation is needed here.

Cut-away views of the four drivers.

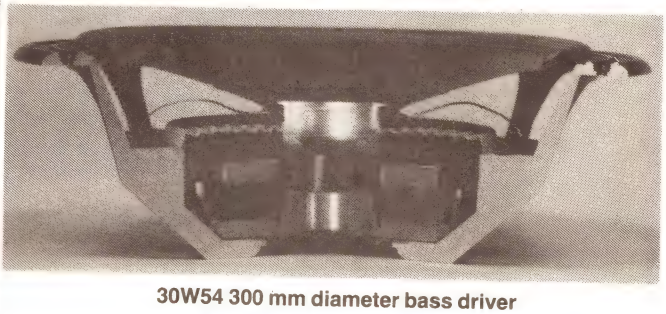


D21AF 21 mm diameter tweeter



D28AF 28 mm diameter treble tweeter

D76AF 75 mm diameter mid-range



30W54 300 mm diameter bass driver

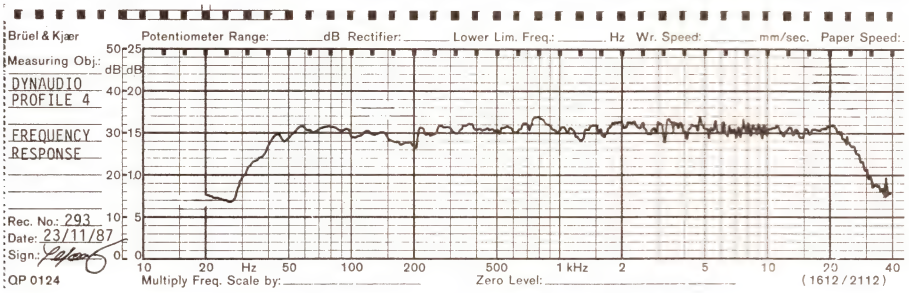


Figure 4. Frequency response of the Profile 4. The response is flat within ±4 dB between 40 Hz and 25 kHz. At –10 dB (half 'loudness') the response extends from 30 Hz to 30 kHz!

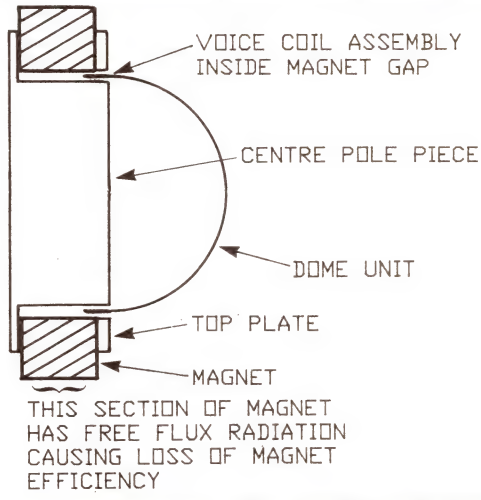


Figure 1. A conventional dome driver has the magnet assembly surrounding an inner pole piece, the voice coil occupying the gap between them. Flux loss from the magnet reduces magnetic efficiency, affecting performance of the driver.

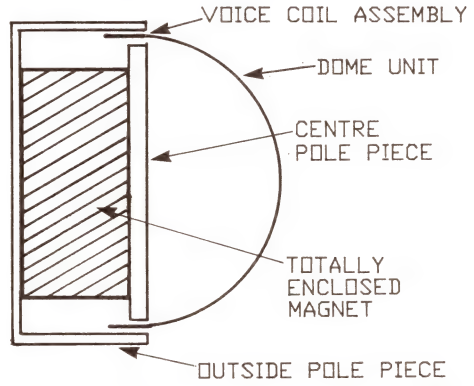


Figure 2. Dynaudio's "centre magnet system" totally encloses the magnet by placing it centrally and completing the magnetic circuit with the outside pole piece and centre pole piece.

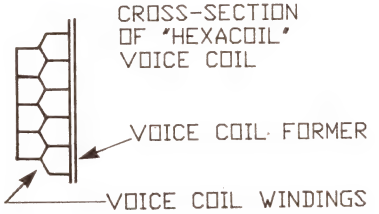


Figure 3. All drivers in the speaker system share the "hexacoil" voice coil system This employs hexagonal-shaped wire to wind the voice coil which leaves no air space between turns, locks the turns rigidly together and results in better thermal performance.

A ready-built crossover unit is supplied with kits. To both preserve the integrity of the input signal and to do justice to the superb quality of the drivers, the crossover has been constructed using the finest available components. All capacitors are metalised polypropylene types, chosen for vanishingly low dielectric absorbtion, high frequency performance and a reduced inductive component. Both inductors are air cored types, L1 having a dc resistance of less than 0.1 Ohms and L2 less than 0.4 Ohms.

To the ear

The subjective performance of the Dynaudio Profile 4 system is extremely good. The speakers have that "very expensive" sound throughout the whole frequency range. On massed choral and orchestral works, they project a huge presence with a characteristically colouration-free sound. As could be expected from looking at the frequency response measurements (Figure 1), the audible result is extremely smooth and balanced. Bass end performance is as good as the computer alignment (Figure 2) predicts.

System construction

The kit is supplied with fully built cabinets finished in real wood veneer and fully assembled crossover networks. A choice of cabinet finishes is available. If you feel you would like to construct your own system from the ground up, detailed cabinet plans have been provided. All material, with the exception of the back and bottom panels, is 25 mm particle board. The back ▷

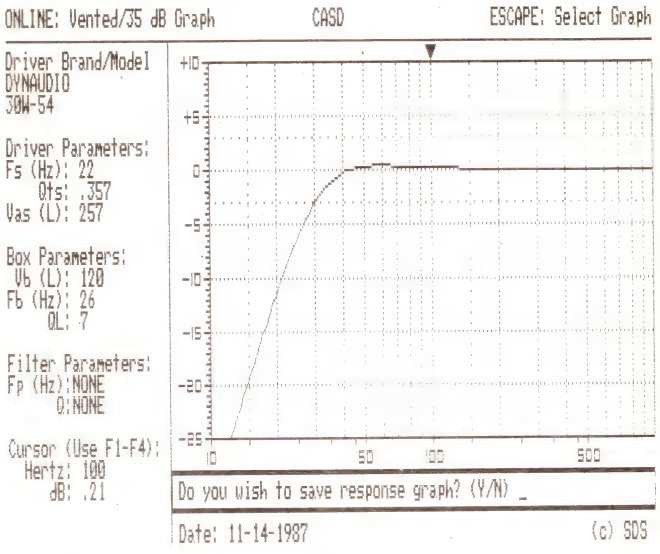
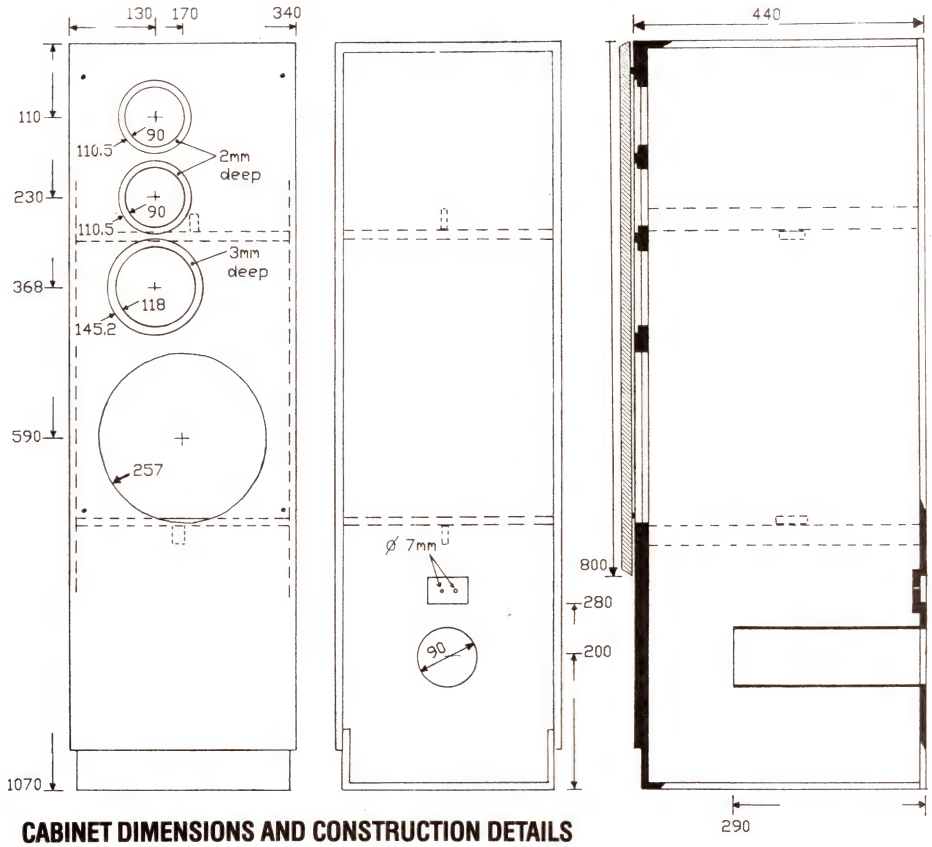
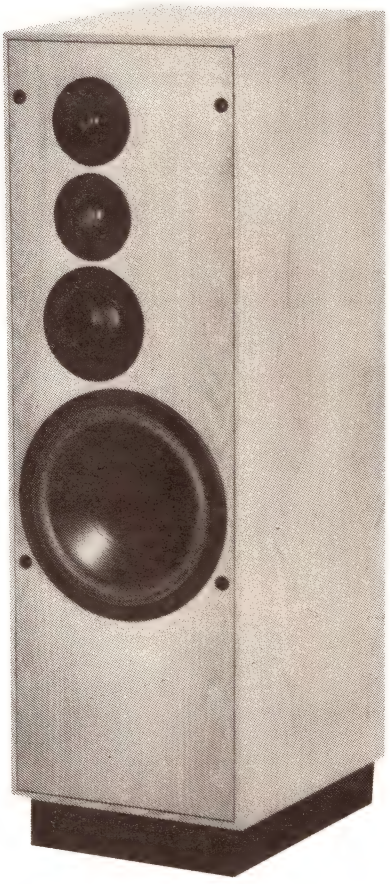
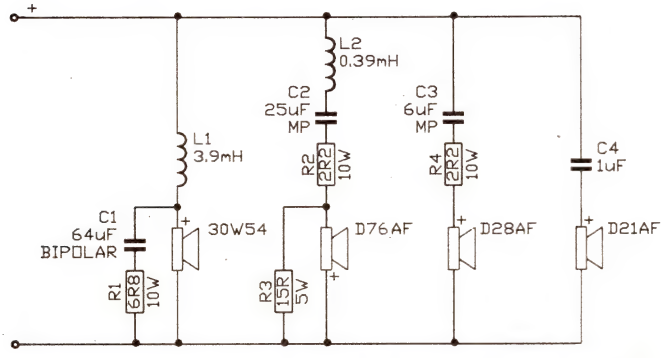


Figure 5. The bass end design was worked out with a computer program that employs the Thiele-Small parameters to optimise the response. This is a printout of the finalised bass response with the port and box dimensions optimised to get this result. As you can see by comparing this with Figure 4, the prediction and the performance closely agree.





CABINET DIMENSIONS AND CONSTRUCTION DETAILS



Circuit diagram of the Profile 4. Note that the D76AF mid-range driver is connected in reverse polarity to the other drivers.

and bottom panels are made from craftwood, also known as customwood. All joints are to be glued with PVA woodworking adhesive, taking note of the double thickness front baffle and the bracing arrangements. Cut the holes for the drivers making sure to rout each one to the required depth.

Once your cabinets have been constructed and left to dry for at least 24 hours, run a bead of silicone or similar material around the inside of all wood joints. This will ensure that no air leaks are present in the final assembly.

Construction of the crossovers is quite straightforward, all parts being glued onto a piece of scrap chipboard. Bostik hot glue is excellent for this purpose. Hardwire all components, taking note that the mid-range is connected out of phase with the other drivers. Mount all capacitors lying down and the inductors at opposite ends of the board to minimise inductive

WHERE TO GET THE PROFILE 4 KIT

NSW

Audio One
71 Military Rd
Neutral Bay 2089
(02)953 6001

The Hi-Fi Shop
Shop 4, 127 Forest Rd
Hurstville 2220
(02)570 8163

Bambach Electronics
672 Hunter St
Newcastle 2302
(049)24996

Wollongong Hi-Fi
481 Crown St
Wollongong 2500
(042)28 3773

QLD

Downtown Hi-Fi
64 Charlotte St
Brisbane 4000
(07)229 0611

Hiway Sound Centre
Cnr Grace & Atherton Sts
Mount Isa 4825
(077)43 6275

NT

Sound Spectrum
51 Stuart Highway
Darwin 5790
(089)81 5060

SA

Miltronix Hi-Fi
125 Payneham Rd
St Peters 5069
(08)42 3781

Aslin Hi-Fi
41 Commercial St West
Mount Gambier 5290
(087)25 6000

WA

Alberts Hi-Fi
396 Murray St
Perth 6000
(09)322 4409

Victoria

Trevor Lees Audio
114 High St,
Kew 3101
(03)682 2315

Tivoli Hi-Fi
155 Camberwell Rd
East Hawthorn 3123
(03)813 3533

Raytronics Hi-Fi
130 Marong Rd
Bendigo 3550
(054)43 6434

ACT

Stereo Warehouse
32b Wollongong St
Fyshwick 2609
(062)80 4533

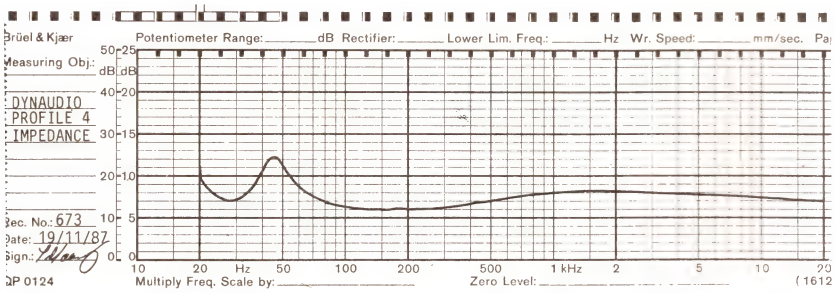


Figure 6. Impedance plot of the profile 4 is relatively smooth with no large excursions within the audio range.

coupling. Check your wiring carefully before installing the crossover in the cabinet.

Mount the crossover on the back of the cabinet, above the brace adjacent to the terminals and ensuring that you have leads long enough to reach both the terminals and the drivers. Screw the terminals in place, making sure to seal around the hole with silicone sealant or a similar substance. Solder the leads onto the terminals, paying particular attention to the polarity. Now you should fit the damping material. You will need a piece about 7200 mm x 400 mm x 50 mm of high density polyurethane foam, which is available from Clark Rubber stores. The damping material should cover every panel entirely, with the exception of the front baffle, and can be glued or stapled in place.

You should now screw the drivers in place, once again sealing around the holes with silicone sealing compound. It is important to have no air leaks whatsoever, except of course for the bass reflex port.

PARTS LIST

2 x Dynaudio 30W54 woofers
2 x Dynaudio D76AF midrange drivers
2 x Dynaudio D28AF tweeters
2 x Dynaudio D21AF super tweeters
2 x speaker terminal blocks
Selection of suitable self-tapping screws
2 x cabinets (see text)
2 x bass ports, PVC pipe 84 mm ID x 290 mm long
8 x male grille studs
8 x female grille studs

Crossover parts (two sets required)

L1	3.9 mH, 0.1 ohm
L2	0.39 mH, 0.4 ohm
C1	64 uF/50 V bipolar
C2	25 uF/50 V metalised polypropelene
C3	6 uF/50 V metalised polypropelene
C4	1 uF/50 V metalised polypropelene
R1	6R8, 10 watt resistor
R2	2R2, 10 watt resistor
R3	15R, 5 watt resistor

Miscellaneous

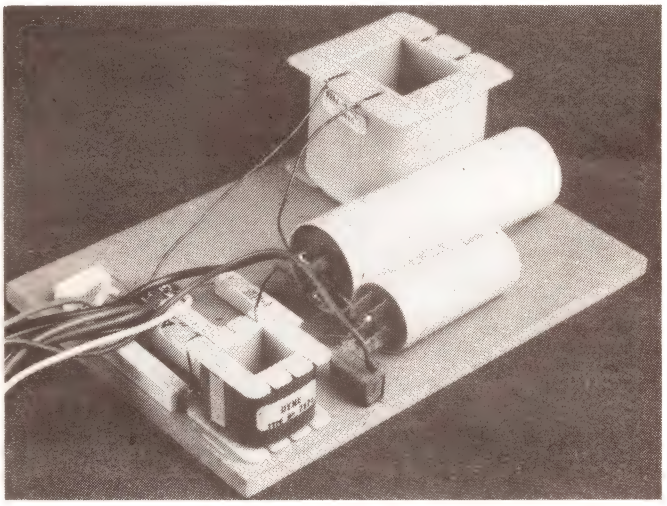
One piece of scrap chipboard 250 mm x 180 mm;
quantity of good quality cable for internal wiring;
7200 mm x 400 mm x 50 mm high density polyurethane foam.

Kit price:
$3600 with pre-built boxes, $2368 without boxes, both with pre-built crossovers.

For those tackling construction from scratch:

Driver prices: 30W54 – $518 ea., D76AF – $248 ea., D28AF – $198 ea., D21AF – $188 ea.

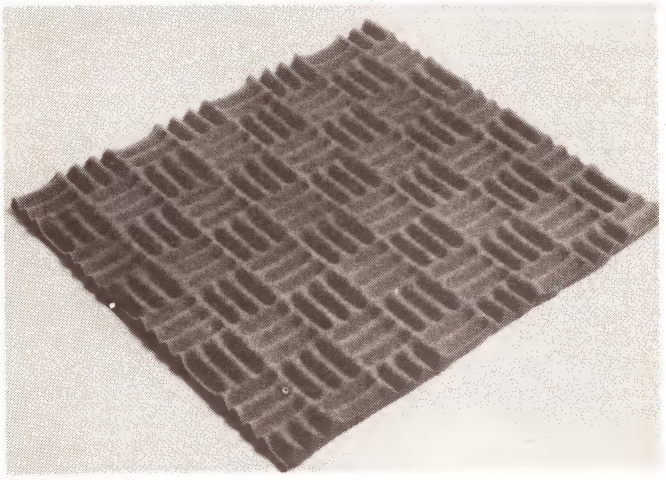
Pre-built crossovers: $169.00 ea.



One of the ready-built crossovers supplied with kits. If you're building your own, they should be constructed on a piece of chipboard in a similar manner and wired according to the circuit diagram.

Your speakers are now ready to be tested. Before powering up, connect a 1.5 volt battery to the input terminal with the positive side of the battery to the positive terminal. The woofer cone should move outwards. If it moves inwards, you have made a mistake in your wiring and will need to re-check the connections. If everything checks out OK, hook up your speakers, select low volume and play some music. Once you are sure each driver is functioning correctly, advance the volume control and sit back and enjoy your new speakers.

We're sure you will be very impressed!



The pre-built boxes supplied with kits have this "Sonex" damping material fitted.

A "musical instrument digital interface" (MIDI) unit for the Microbee

Geoff Swan

With MIDI interface connections now pretty well standard on a whole variety of electronic musical equipment, software control of a system or setup using a home computer is not only feasible, but offers many opportunities for creative control of a system. This project was designed to interface a Microbee with a MIDI system, affording computer control at modest cost.

NO DOUBT many of our musically minded readers will be familiar with the MIDI (Musical Instrument Digital Interface) system used to connect electronic instruments such as keyboards, sequencers, drum machines and signal processing equipment to each other. Many enthusiasts have also discovered the advantages of interfacing these instruments with personal computers for expanded control and additional features.

Although there are now several personal computers available which come equipped with the necessary interfacing and electronics, if you already own a computer of some sort it seems a shame to have to exchange it or purchase another one just to get MIDI capability.

This simple project will allow control of MIDI devices from virtually any computer fitted with an 8-bit parallel port and in our case has been designed for use with the popular Microbee computer. The project provides both MIDI transmit from the computer and receive from external devices and although in this project these modes are manually switched, most applications will make use of only the transmit mode.

A modified version of the circuit and pc board has been developed to suit the IBM PC and compatible machines. We hope to present details on this shortly.

The design is built around a "universal asynchronous receiver transmitter" device, or UART. The COM8017 manufactured by Standard Microsystems is specified, but the General Instruments AY-3-1015D may be employed (see the accompanying note). The MIDI system employs serial digital signals (pulses, one after another arranged in a prescribed order), while the Microbee's "user port" is a parallel type (the signal appears as highs and lows in a prescribed manner on a group of eight lines). The UART's job is to convert the parallel data at the Microbee's port to serial data at the MIDI interface connector.

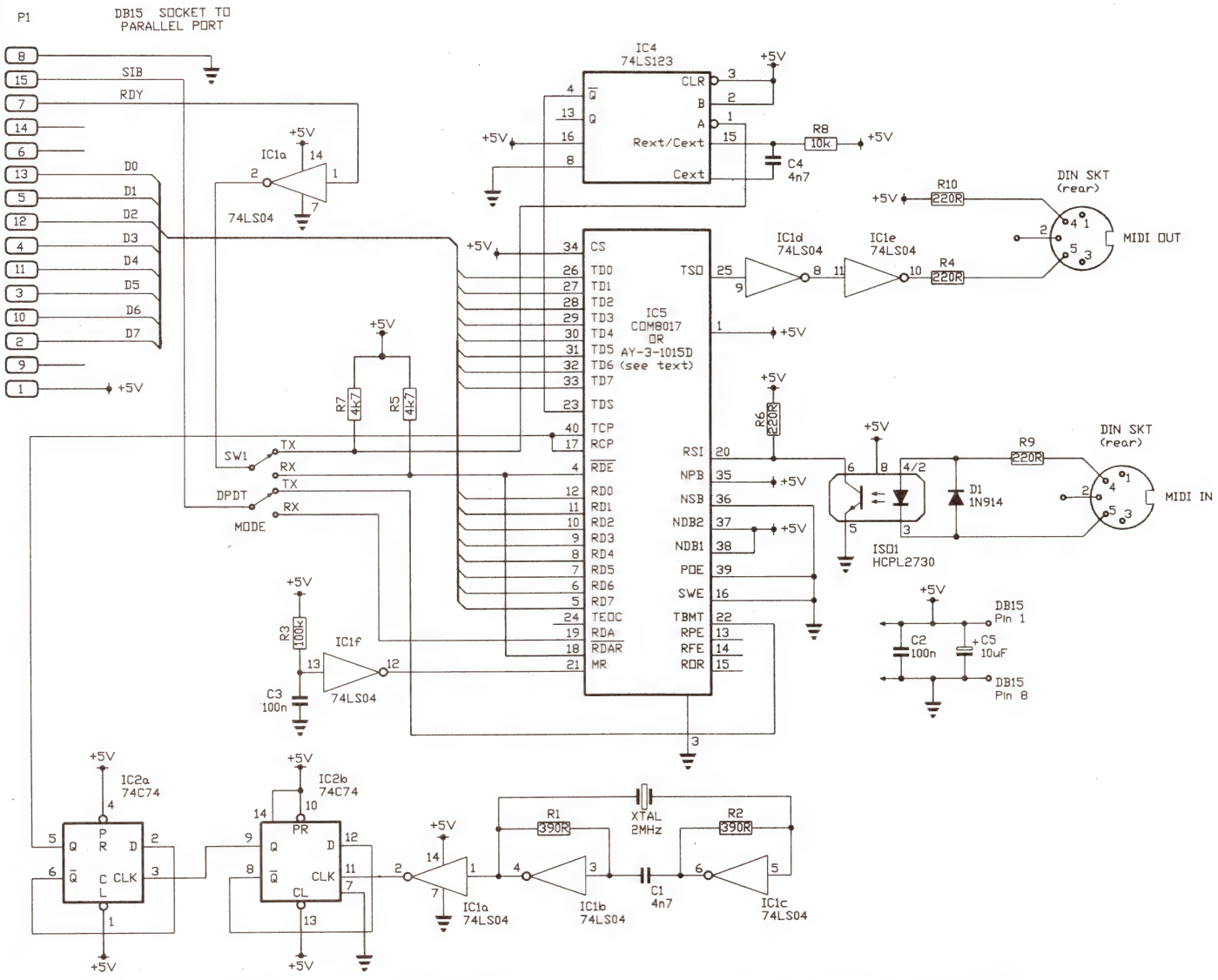
As can be seen from the circuit diagram and accompanying photographs, the unit is relatively simple, and all the circuitry is housed on a single, square printed circuit board measuring 110 mm a side. The computer connector (a 15-pin "D" type), the two MIDI connectors (DIN sockets) and 'transmit-receive' switch are all mounted along one edge for convenience. The circuitry is powered from the 5 V supply available on the Microbee's user port. An opto-isolator has been employed to electrically isolate the receive line from the interface circuitry. Four other logic chips "glue" the circuit together. A complete description of the circuit is found in the "Circuit Description" panel accompanying the circuit diagram.

Drive your MIDI system from a Microbee with our simple interface unit.

All components are readily available and intending constructors should have little difficulty obtaining parts. A number of firms have indicated they will likely stock the project as a complete kit. Check the "Project Buyers Guide" in this issue for details.

Construction

Before starting construction, make a thorough examination of the pc board to check that all the holes are drilled correctly and ▷



CIRCUIT DESCRIPTION

The design is based around the COM8017 UART. A useful feature of this device is the ability to program various operating parameters by the use of external pin connections. In our application, the parameters are dictated by the applicable MIDI standards, so we can hard wire these pins to give us the required setup.

Table 1 shows how the various pins of the UART are connected in this project and examination will show that the configuration is set to give one start bit, eight data bits, no parity and one stop bit. The signal names differ slightly between the two types of UART and Figure 1 shows pinout details for comparison.

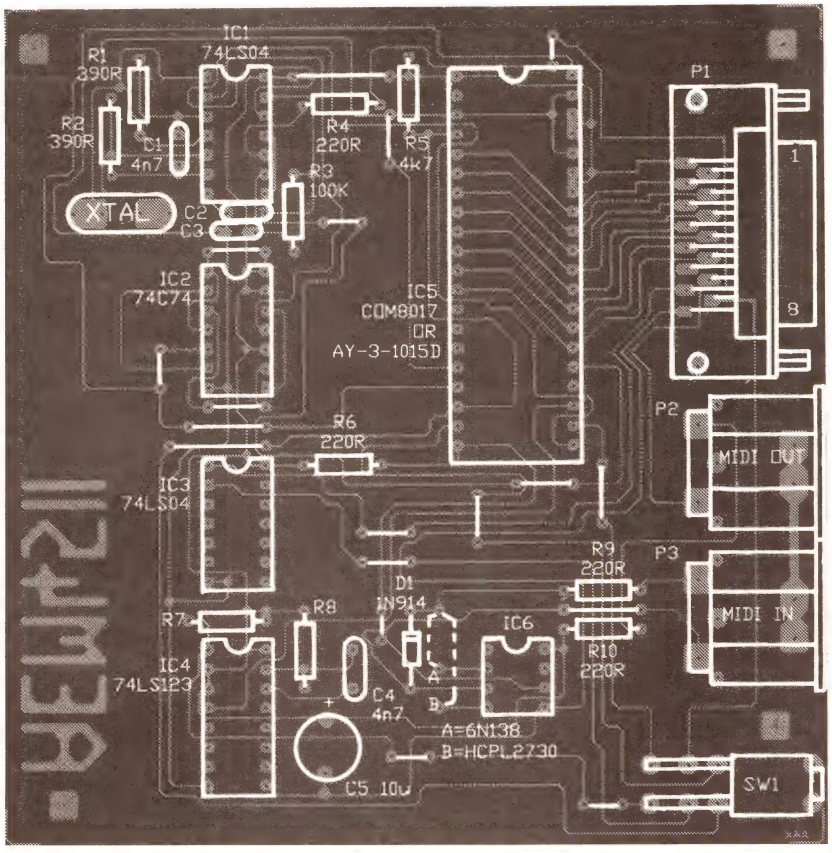
To provide the clock signal for the UART, a 2 MHz crystal oscillator is incorporated in the design. The MIDI interface specifies a data transfer speed of 31.25 kilobaud and the UART requires a clock signal at 16 times the baud rate. To accomplish this, the 2 MHz oscillator is divided by IC2a and IC2b to give the required 500 kHz clock pulse. This is then applied to pin 17 of the UART.

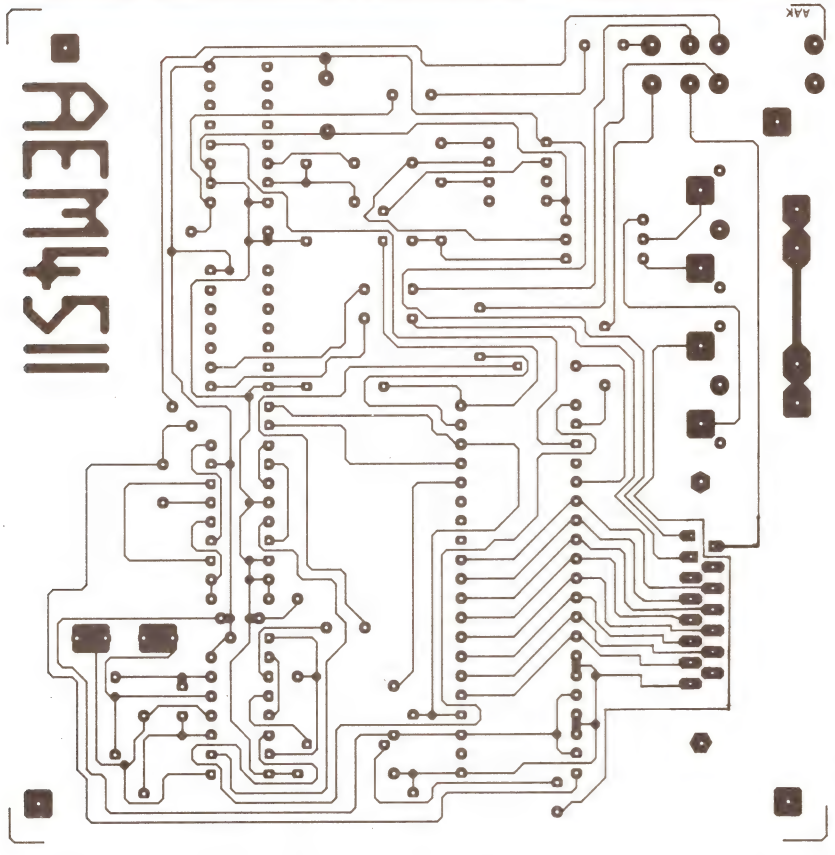
In the transmit mode, the RDY signal from the Microbee parallel port is inverted by IC1a and used to trigger the monostable, IC4. The resulting pulse from the monostable is used to strobe the transmit data from the parallel port into the UART's transmit buffer. The UART will start to transmit this data at 31.25 kbaud and as soon as the transmit buffer is empty, the UART will output the TMBT signal. This signal is used to drive the STB input on the Microbee port and signifies that the interface is ready to receive another character. This sequence is then repeated for each character to be transmitted.

In the receive mode, when a character has been received from the serial MIDI input, the UART will assert the RDA signal. This signal is fed to the STB input line of the Microbee's port. The Microbee will then assert RDY, which is used to enable the receive data out to the port and also resets the RDA signal (RDAR). In the same way as transmit, this cycle is repeated for each character received.

The interface draws its power from the Microbee's parallel port connector via pins 1 and 8 of the DB15 connector and the serial input and output are buffered in accordance with the MIDI 1.0 specification with the input being optically isolated by IC6.

NOTE: The MIDI signalling speed here of 31.25 kilobaud is somewhat above the top baud rate of 25 Kb specified for the AY-3-1015D UART, but well within the 40 Kb maximum rate specified for the COM8017. However, a prototype we assembled here at AEM using the AY-3-1015D worked fine.





AEM4511 PARTS LIST

Resistors all ¼ watt 5%

R1-R2	390R
R3	100k
R4	220R
R5	4k7
R6	220R
R7	4k7
R8	10k
R9-R10	220R

Capacitors

C1	4n7 ceramic
C2, C3	100n ceramic
C4	4n7 ceramic
C5	10u/16 V RB electro.

Semiconductors

IC1	74LS04
IC2	74C74
IC3	74LS04
IC4	74LS123
IC5	COM8017/AY-3-1015D UART
IC6	6N138 or HCPL2730/1
D1	1N914, 1N4148

Miscellaneous

AEM4511 pc board; one DB15 pc board mounting socket; two DB15 IDC plugs; one metre 15-way ribbon cable; two 5-pin DIN (180 degree) pc board mount sockets; one 2 MHz crystal; one DPDT right-angle pc mount toggle switch; one metre tinned copper wire.

Estimated cost: $75 – $85

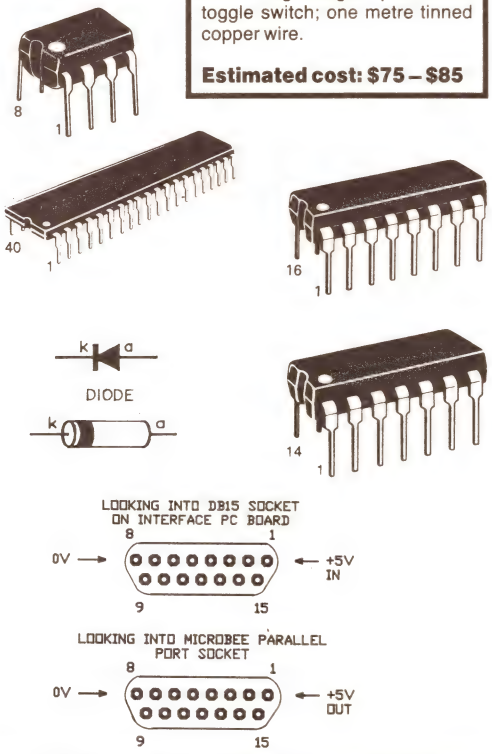
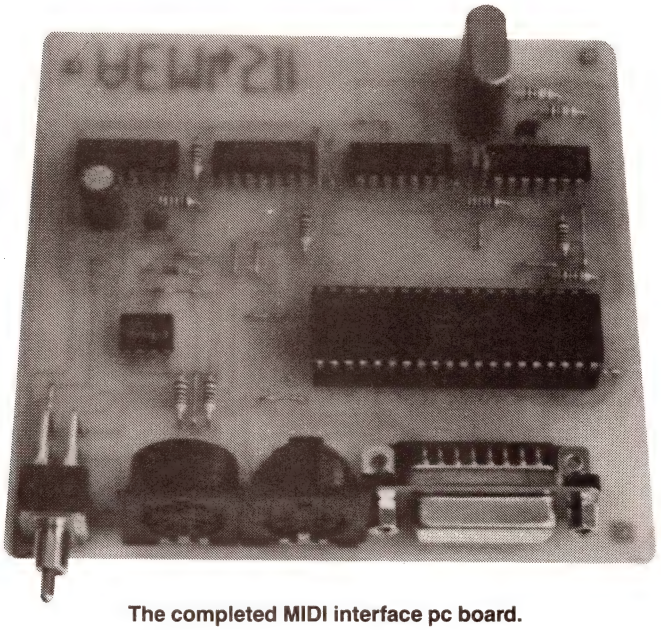


Figure 2. This diagram shows the pin numbering and power supply connections to both the Microbee parallel port connector and the DB15 connector on the interface. The cable used to link these two should be a straight through type with pin 1 of the Microbee socket connecting to pin 1 of the interface socket.

that there are no shorted or broken tracks. The pc board has quite a few very fine tracks, many of which run close to one another. A good visual check will save a lot of frustration late

It is best to start construction by first fitting all the wire links on the board. There are quite a few of these so you will need to pay attention to the component overlay. Note that the link



The completed MIDI interface pc board.

alongside the opto-isolator can be fitted in two possible positions depending on the type of opto-isolator chip you are using. Because of the fine tracks and close spacing of the pc board, you will need to use a fine-tipped soldering iron and small gauge solder in order to make a neat job and not create unwanted shorts.

Once all the links are fitted, you can proceed by fitting the resistors and capacitors. There are only a few of these, so you

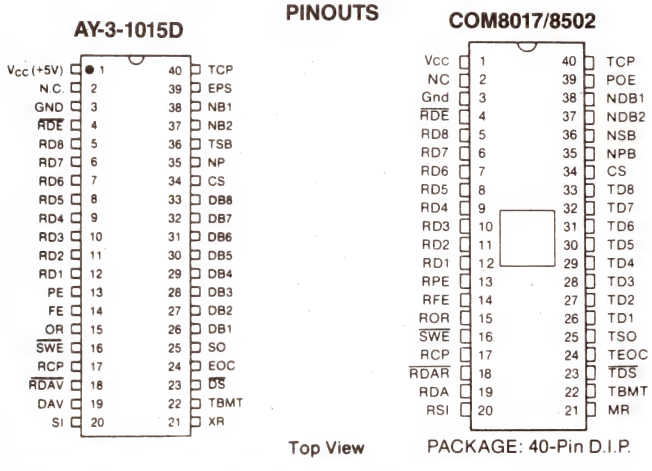


Figure 1. AY-3-1015D and COM8017/8502 pinouts

TABLE 1. UART pin signals and their uses here.

PIN	LABEL	FUNCTION	CONNECTED TO	SET TO
4	RDE-0	REC DATA EN.	USED IN RX MODE. SWITCHED TO PORT RDY-1 SIGNAL	TX = 5V RX = RDY
16	SWE-0	STATUS WORD ENABLE	0V	ENABLE
17	RCP	RX CLOCK	500kHz CLOCK	16xBAUD RATE
19	RDA-1	RX DATA AVAILABLE	USED IN RX MODE. SWITCHED TO PORT STB-0 INPUT	TX = NC RX = STB
22	TMBT-1	TX BUFFER EMPTY	USED IN TX MODE. SWITCHED TO PORT STB-0 INPUT	TX = STB RX = NC
23	TDS-0	TX DATA STB	USED IN TX MODE. SWITCHED TO PORT RDY-1 SIGNAL	TX = RDY RX = 5V
34	CS-1	CONTROL STB	5V	ENABLE
35	NPB	NO PARITY BIT	5V	NO PARITY
36	NSB	NUMBER STOP BITS	0V	1 STOP BIT
37	NDB2	NUMBER DATA BITS/CHAR	5V	8 DATA BITS
38	NDB1		5V	
39	PDE	ODD/EVEN PARITY	X (DON'T CARE)	NO PARITY
40	TCP	TX CLOCK	500kHz CLOCK	16xBAUD RATE

should not experience any problems. The only capacitor which is polarised is the 10 uF electrolytic, C5, and the overlay shows the correct orientation.

The next step is to fit the various hardware items to the pc board. These are the DB15 socket, the two 5-pin DIN sockets and the switch. These items will only fit in the board in the correct orientation, so you should not get into trouble.

With the hardware items fitted to the board, you can continue by fitting all the semiconductors. Take care with the orientation of the diode and the ICs. It is advisable, though not essential, to use a socket for the UART, IC5. To complete construction of the board, solder the crystal in place. Note that the board has been designed to take both the large or small types of crystal. Take care when soldering the crystal in place so that it is not overheated and damaged.

Now that the pc board is assembled, it is time to give it another good visual check. Look for solder splashes or bridges and check that all joints are properly soldered.

At this point, you can make a decision as to how to house the project. We have not included details of a cabinet as some constructors may wish to build the interface into an existing piece of equipment. If you do wish to mount the project in a separate case, any of the popular range of cabinets available from electronics retailers should suffice.

The MIDI specification calls for interconnection between MIDI devices by means of a shielded twisted pair with the shield connected to pin 2 of the DIN connector at both ends of the cable. In this project, we have left the pc board pads associated with pin 2 of the DIN sockets disconnected rather than connect them to the "dirty" computer ground. If you are intending to mount the project in a metal enclosure, you should run a separate short wire from each of these pads and connect the other ends to the same ground connection on the case. Do not simply link the two pads together and use a single wire to the grounding point.

Testing

Once you have given the completed board a good inspection, you can proceed to test the unit. Take particular care when assembling the cable which links the computer's parallel port to the board and ensure that the power supply connections are correct. Figure 2 shows where the supply pins are located on the Microbee's port as well as the DB15 connector on the project. If you are using ribbon cable and IDC type connectors for the cable it is quite easy to get things the wrong way around, so take care.

When you are satisfied that all is in order, you can connect the project to the computer and turn the computer on. Before doing anything else, you should check across the power supply rails to see that the +5 V is present and is of the correct polarity. If everything is OK, you can connect your MIDI instrument and try running the software. If you don't have a midi instrument, you can use an oscilloscope to examine the serial output from ▷

```
00100 REM /*
00110 REM /* midi interface program
00120 REM /*
00130 REM * 00 01 07
00140 REM /*
00150 SIRS(1000)
00160 DIM N(256)
00170 CLS
00180 PRINT "Test menu:"
00190 PRINT
00200 PRINT "     a) enter bytes to output."
00210 PRINT "     b) output note string."
00220 PRINT "     c) input bytes from port."
00230 PRINT
00240 PRINT "Selection: ";
00250 K1$ = KEY:IF K1$="" THEN 250
00260 IF K1$ < "a" OR K1$ > "c" THEN 250
00270 IF K1$ = "a" THEN GOSUB 310:GOTO 180
00280 IF K1$ = "b" THEN GOSUB 400:GOTO 180
00290 IF K1$ = "c" THEN GOSUB 530:GOTO 180
00300 END
00310 REM /* enter byte table */
00320 CLS
00330 PRINT "Byte table entry: (max 255)"
00340 I=1
00350 PRINT "Enter byte "I" (-ve value to end): ";
00360 INPUT "" N(I)
00370 IF I=255 OR N(I)<0 THEN LET 0=I:RETURN
00380 I=I+1:GOTO 350
00390 RETURN
00400 REM /* output note table */
00410 I=1
00420 PRINT "Output bytes. < > vary speed."
00430 PRINT "Any other key to stop."
00440 IF T<5 THEN LET T=5
00450 OUT 0,N(I)
00460 FOR J=1 TO T:NEXT J
00470 IF I=0 THEN LET I=1:GOTO 440
00480 I=I+1
00490 K1$=KEY:IF K1$="" THEN 440
00500 IF K1$="." THEN LET T=T+1:GOTO 440
00510 IF K1$="," THEN LET T=T-1:GOTO 440
00520 RETURN
00530 REM /* input bytes from port */
00540 PRINT "Input bytes. Hit any key to stop."
00550 B=IN(0)
00560 PRINT B;"  ";
00590 K1$=KEY:IF K1$="" THEN 550
00600 RETURN
```

the "MIDI OUT" DIN connector whilst running the software. Don't forget to set the switch to the transmit position, which will be down if the specified switch type is used.

If you experience any difficulties, check the wiring of the interconnecting cable and if possible, use an oscilloscope to check the operation of the on-board clock.

The software

The software presented here is intended as a basic means of testing the unit and sending or receiving MIDI data. With the program entered and running in your computer and the interface connected to your MIDI instrument, choose option "A" from the menu and enter a string of appropriate bytes to be sent to the instrument. When all the bytes have been entered, type in a negative value to end and return to the menu. Next you should choose option "B" from the menu and the bytes just entered will be sent to the instrument. The program listing is quite short and straightforward and the on-screen instructions should lead you through the operation without any problems.

If you would like to have more sophisticated control of your MIDI device, it should not be too difficult to write more advanced software using the version printed here as a guide. You will need to know some details of the MIDI protocol and commands, and these can be found in the references listed here.

References

A detailed description of the MIDI standard can be found in the article *"Esperanto for Synths"* published in the October-December 1983 issue of Sonics magazine.

— from page 90

cent inductors.

To continue the example of the bandpass filter in Figure 4.12, this filter would be tuned as follows: Start with all links connected except No.1. With a sensitive RF meter connected across it, tuned circuit L(1)C(1) can now be tuned for maximum reading at 28.886 MHz. The input connectors are now short-circuited, links 1 & 2 are removed, and LA(2)CA(2) tuned to 32.395 MHz. Links 1 & 2 are connected, the short-circuit removed from the input terminals, links 4 & 5 are removed, and LB(2)CB(2) is tuned to 25.757 MHz. Link 5 is connected, link 6 removed, and L(3)C(3) is tuned to 28.886 MHz. Link 4 is connected, link 7 is removed, and LA(4)CA(4) is tuned to 31.068 MHz. Links 6 & 7 are connected , links 9 & 10 are removed, the output connections are short-circuited, and LB(4)CB(4) is tuned to 26.857 MHz. Link 10 is connected, the output connectors are open-circuited, and L(5)C(5) is tuned to 28.886 MHz. Links 1, 4, 6, and 9 are connected into the circuit, all other links are removed, and the filter is ready for testing and use.

An alternative to using an oscillator-meter combination for tuning is to use a grid dip oscillator (GDO) together with a frequency meter. A GDO by itself is nowhere near accurate enough in frequency calibration to be used for the alignment of elliptic, or any other kind of filters. If your GDO does not have any provision for attachment of a frequency meter, a single turn loop connected to the input of the frequency meter can be mounted near the 'earthy' end of the GDO coil.

After each of the tuned circuits in the filter is isolated, the GDO is brought just near enough to the circuit being tuned to get a reading, and the inductance of the coil is altered until the GDO minimum is at the correct frequency as measured on the frequency meter. Even though it is not strictly necessary to earth each tuned circuit when using the GDO-frequency meter method, it is sound practice to do so.

Testing consists of measuring the frequency response and making minor adjustments to the tuning to get the designed response. Frankly, if the response is satisfactory rather than exact, don't touch the thing. It is not an easy job to work out which part of the filter needs adjustment to produce a given effect on the overall response.

If you enjoy experimenting with filters, one way to go is to build the same filter, but at a frequency in the audio range where adjustments are much less critical. Then you can deliberately mistune various parts of the filter and see what the effects are on the frequency response. In this way you can get your experience on a filter that is easy to adjust and, provided that you keep a results book in which you record that experience, you will then be able to tackle high frequency filters with much more confidence.

Additional reading

For those intrepid souls who want to have a go at synthesising their own elliptic LC filters, the classic paper is *"On the design of filters by synthesis"* by R.Saal and E.Ulbrich (of Telefunken GmbH) in IRE Transactions on Circuit Theory, December 1958 pp 284-327. This paper also gives the original tables for normalized LP elliptic filters of order 6 to 11 that are reproduced in Williams' book. In the paper, the remainder function method described on pp 312-313 is the part that complicates the computer programs that calculate component values. The theory of these programs is presented in G.Szentirmai, *"Theoretical basis of a digital computer program package for filter synthesis"* in 1st Allerton Conf. Circuit and System Theory pp 37-49 1963.

Both of the above papers, (without any tables) together with many more of the landmark papers on the subject, are reprinted in *"Computer-Aided Filter Design"* Edited by G.Szentirmai, published by IEEE Press 1973.

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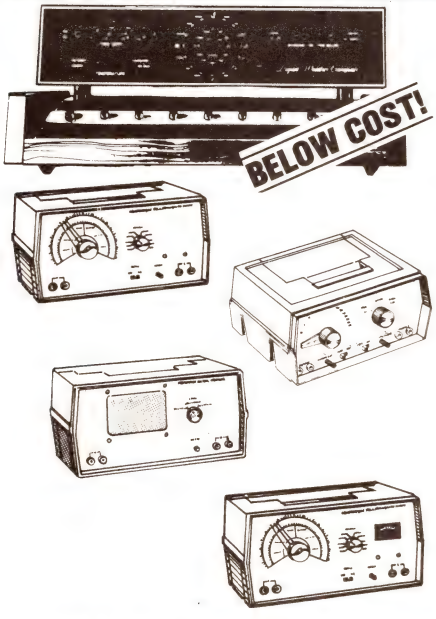

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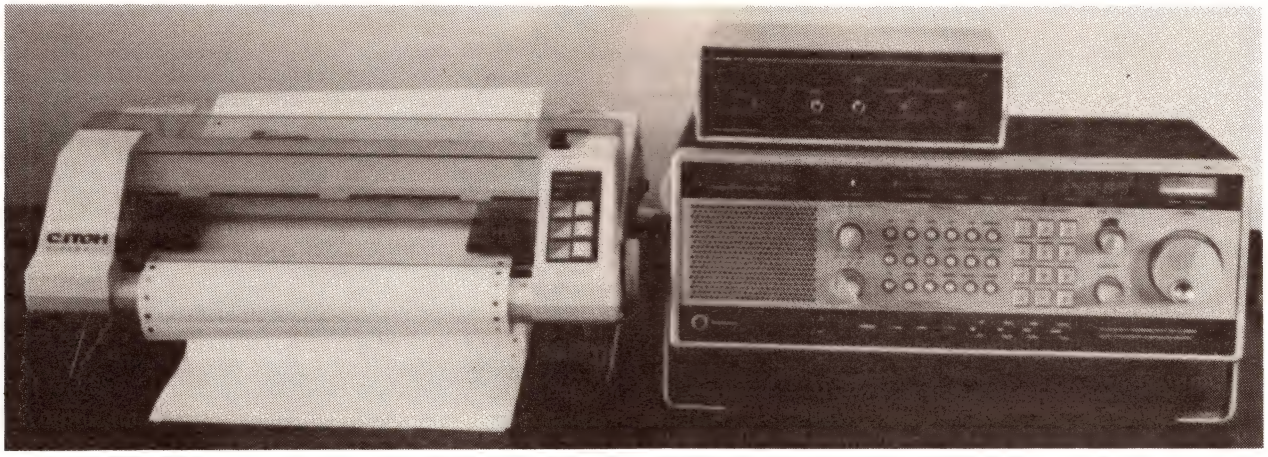


A "stand-alone" Morse/RTTY decoder

This project is hooked up between the audio output of a receiver and a dot matrix printer. It will decode and print out any Morse or radioteletype transmissions you tune in. If you don't have a computer – here's the modern way to get into "electronic" RTTY and Morse reception. If you do have a computer, free it up for other uses!

MANY READERS will be familiar with the concept of using a personal computer to decode and display Morse code or radioteletype (RTTY) information from a shortwave radio receiver. Various interfaces and some quite clever software have been published for this purpose in the past (such as the AEM3500 "Listening Post" by Tom Moffat) and most designs have proved very popular. The greatest disadvantage of using this method however, is that the computer can't be used for any other tasks whilst you are monitoring the airwaves.

This project, from the R&D division of Dick Smith Electronics, overcomes the problem by putting the decoder, computer and software all in one integrated unit and using a parallel printer as the output device. the unit is constructed on one single-sided printed circuit board which holds the majority of components, and housed a smart plastic instrument case. It is powered from a low-cost dc plugpack.

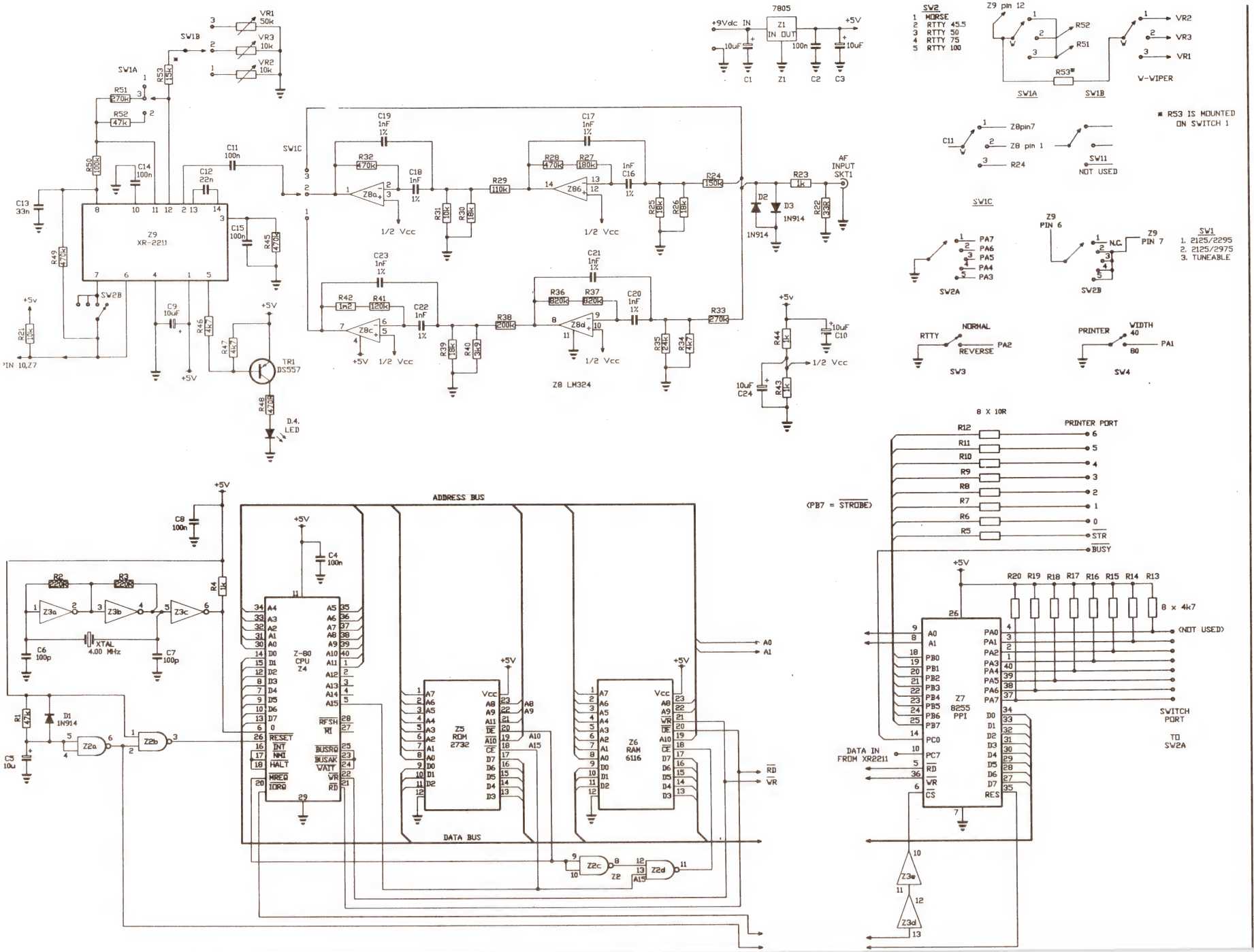
The decoder is comprised of two main sections, analogue and digital, as can be readily seen from the circuit diagram over the next page. The analogue section includes both narrow and wide filters for RTTY and a tone detector/demodulator circuit based around the popular XR2211 IC. The digital section is based around a Z80 microprocessor running at 4 MHz with a minimum number of support chips to help reduce cost and complexity.

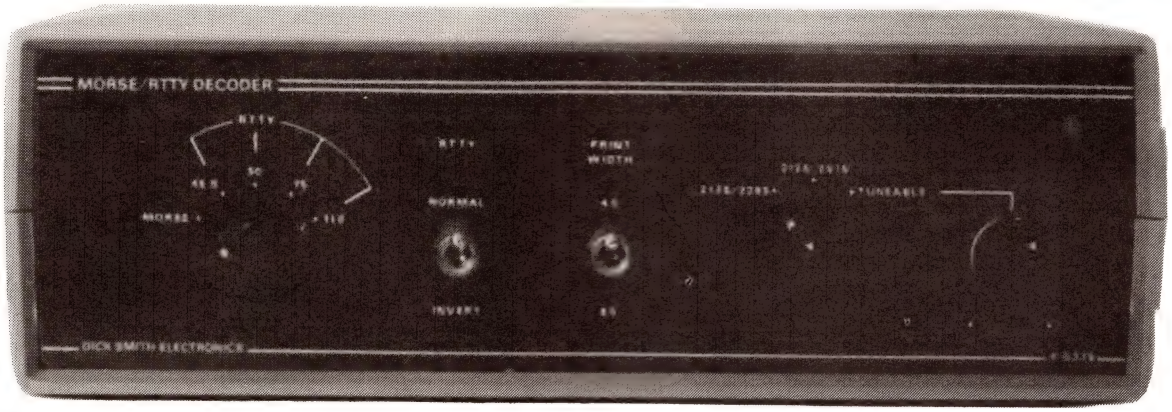
The front panel switches on the decoder allow a choice between Morse code or a variety of standard RTTY baud rates. The printout is formatted with the automatic insertion of carriage return/line feeds that take place after either 40 or 80 received characters. Carriage returns and line feeds that are decoded during reception are executed as they are received so that, in the case of standard RTTY transmission, the original formatting of the transmitted text is preserved.

All you need is a shortwave receiver, the decoder and a printer! The decoder is housed in a smart plastic instrument case and plugs into the auxilliary audio output of your receiver.

The Morse code decoding program self-tracks over a wide range of transmission speeds, from very slow, around 5 words per minute (WPM), to more than 40 WPM. As the tone of a Morse signal may vary in pitch from one source to another, a control is provided to tune the tone detector over a range from 800 Hz to 3 kHz. RTTY polarity can be inverted if required and ▷

This Star Project is from Dick Smith Electronics who will be marketing kits through their stores and dealers; cat. no. K-6339, $159.95 Mail order enquiries to PO Box 321, North Ryde 2113 NSW. (02)888 3200.


7805
+9Vdc IN
+5V
10uF
100n
C1
Z1
C2
C3
SW2
1 MORSE
2 RTTY 45.5
3 RTTY 50
4 RTTY 75
5 RTTY 100
Z9 pin 12
R52
R51
R53*
VR2
VR3
VR1
W-WIPER
SW1A
SW1B
* R53 IS MOUNTED ON SWITCH 1
C11
Z8pin7
Z8 pin 1
R24
SW11
NOT USED
SW1C
SW2A
PA7
PA6
PA5
PA4
PA3
Z9 PIN 6
Z9 PIN 7
N.C.
SW2B
SW1
1. 2125/2295
2. 2125/2975
3. TUNEABLE
RTTY
NORMAL
REVERSE
PA2
SW3
PRINTER
WIDTH
40
80
PA1
SW4
VR1 50k
VR3 10k
VR2 10k
SW1B
SW1A
R53 15K
R51 270k
R52 47k
R50 100k
C14 100n
C11 100n
C12 22n
C13 33n
Z9 XR-2211
C15 100n
R45 470k
R49 470k
SW2B
C9 10uF
R46 4k7
R47 4k7
TR1 DS557
R48 470R
D4 LED
R21 10k
IN 10,Z7
SW1C
C19 1nF 1%
R32 470k
C18 1nF 1%
R29 110k
C17 1nF 1%
R28 470k
R27 180k
C16 1nF 1%
R24 150k
R23 1k
AF INPUT SKT1
Z8a
1/2 Vcc
R31 10k
R30 18k
Z8b
R25 18k
R26 18k
D2 1N914
D3 1N914
R22 33R
C23 1nF 1%
R42 1n2
R41 120k
C22 1nF 1%
R38 200k
C21 1nF 1%
R36 820k
R37 820k
C20 1nF 1%
R33 270k
Z8c
Z8d
R39 18k
R40 2k2
R35 24k
R34 4k7
Z8 LM324
R44 1k
C10 10uF
R43 1k
C24 10uF
8 X 10R
PRINTER PORT
R12
R11
R10
R9
R8
R7
R6
R5
(PB7 = STROBE)
STR
BUSY
R20 R19 R18 R17 R16 R15 R14 R13
8 x 4k7
(NOT USED)
SWITCH PORT
TO SW2A
DATA IN FROM XR2211
Z7 8255 PPI
PA0
PA1
PA2
PA3
PA4
PA5
PA6
PA7
PB0
PB1
PB2
PB3
PB4
PB5
PB6
PB7
PC0
PC7
RD
WR
CS
RES
D0
D1
D2
D3
D4
D5
D6
D7
Z3e
Z3d
C8 100n
C4 100n
R2 220R
R3 220R
R4 1k
Z3a
Z3b
Z3c
XTAL 4.00 MHz
C6 100p
C7 100p
R1 47k
D1 1N914
C3 10u
Z2a
Z2b
ADDRESS BUS
Z-80 CPU Z4
RESET
INT
NMI
HALT
MREQ
IORQ
RFSH
M1
BUSRQ
BUSAK
WAIT
WR
RD
A0
A1
A10
A15
Z5 ROM 2732
Z6 RAM 6116
DATA BUS
Z2c
Z2d
Z2
RD
WR



two RTTY frequency shift options are available: 170 Hz using the tone pair of 2125/2295 Hz as commonly used by amateur stations, and 850 Hz using the tone pair of 2125/2975 Hz as often employed by commercial stations.

Construction

The pc board for this project has a lot of very fine tracks and quite a high track density. Before starting construction, a good visual inspection should be made to check that all holes are drilled correctly and there are no shorted or broken tracks.

Commence construction by first fitting all the wire links. There are quite a few of these and you will need to pay careful attention to the component overlay. Make sure that none of the links contact one another. After fitting all the links, you should solder all the pc board pins in place. These are used to terminate all the flying leads from the pc board and there are quite a few of them. Once all the links and pins are fitted, you can continue construction by fitting all the resistors.

Take special care with the resistors around the filter area as 1% resistors can sometimes be difficult to read and it is easy to make a mistake. If you are in any doubt as to the value of any 1% resistors, use a multimeter to check their value before inserting them. Note that resistor R53 is mounted on the switch SW1 as shown in the wiring diagram.

Resistors R5 to R12 have ferrite beads fitted over their leads. These beads, together with a carefully routed pc board earth track and ground plane, will help to reduce interference from ▷

CIRCUIT OPERATION

The demodulator section of the project is based around an Exar XR2211 FSK demodulator IC. For those of you who are interested in the operational details of this device, a data sheet was published in the October 1985 issue of AEM and we have also published a number of projects based around the chip in recent months.

Audio from the external speaker jack of the receiver is applied to the input socket of the unit where it is attenuated by the network R22 and R23 and clamped by the back-to-back diodes D2 and D3.

The project provides for two different RTTY shift frequencies and each of these has a separate bandpass filter to treat the incoming signal from the receiver.

Reference to the circuit diagram will show that the filters are constructed using all four sections of an LM324 quad op-amp. Two sections are used for each filter and switch SW1 selects which filter output is used as the signal source for the XR221 demodulator. There is a third position of SW1 which bypasses the filters altogether and this is used for the "tuneable" mode.

The 170 Hz shift filter employs the Z8c and Z8d sections of the LM324 and has a bandwidth of about 480 Hz with a centre frequency close to 2200 Hz (it's set at 2208 Hz, to be exact). The 850 Hz shift filter uses Z8a and Z8b to provide a bandwidth of about 950 Hz with a centre frequency set to 2514 Hz.

In this project, the XR2211 is switched between the tone-detect mode for Morse code reception, and the FSK (frequency shift keying) mode for RTTY reception. Switch SW1a is employed to alter the bandwidth of the XR2211 from wide for 850 Hz shift RTTY, to narrow for 170 Hz shift RTTY. The narrow mode is also the most suitable setting for Morse reception. The centre detection frequency of the XR2211 is determined by the values of the three variable resistors VR1, VR2 and VR3. The two preset trimmers VR2 and VR3 are used for RTTY and VR1, on the front panel, is used for Morse tone detect.

The front panel LED shows when the XR2211 is "in lock" during RTTY reception and will flash in time with the dots and dashes during correctly tuned Morse code reception.

The digital section

The digital section of the project is designed around a Z80 CPU. Clock and reset circuits are provided, as well as 2K of RAM, 4K of ROM and an 8255 three-port programmable peripheral interface (PPI) chip.

When power is first applied to the decoder, a power-on reset signal is generated by the charging of C5 through resistor R1 and is applied to both the CPU and the PPI chips. On reset, the CPU starts to execute the program stored in the 2732 ROM, Z5. The ROM is mapped to occupy address locations from 0000H to 0FFFH. The 6116 2K static RAM, Z6, is mapped to memory locations 8000H to 87FFH.

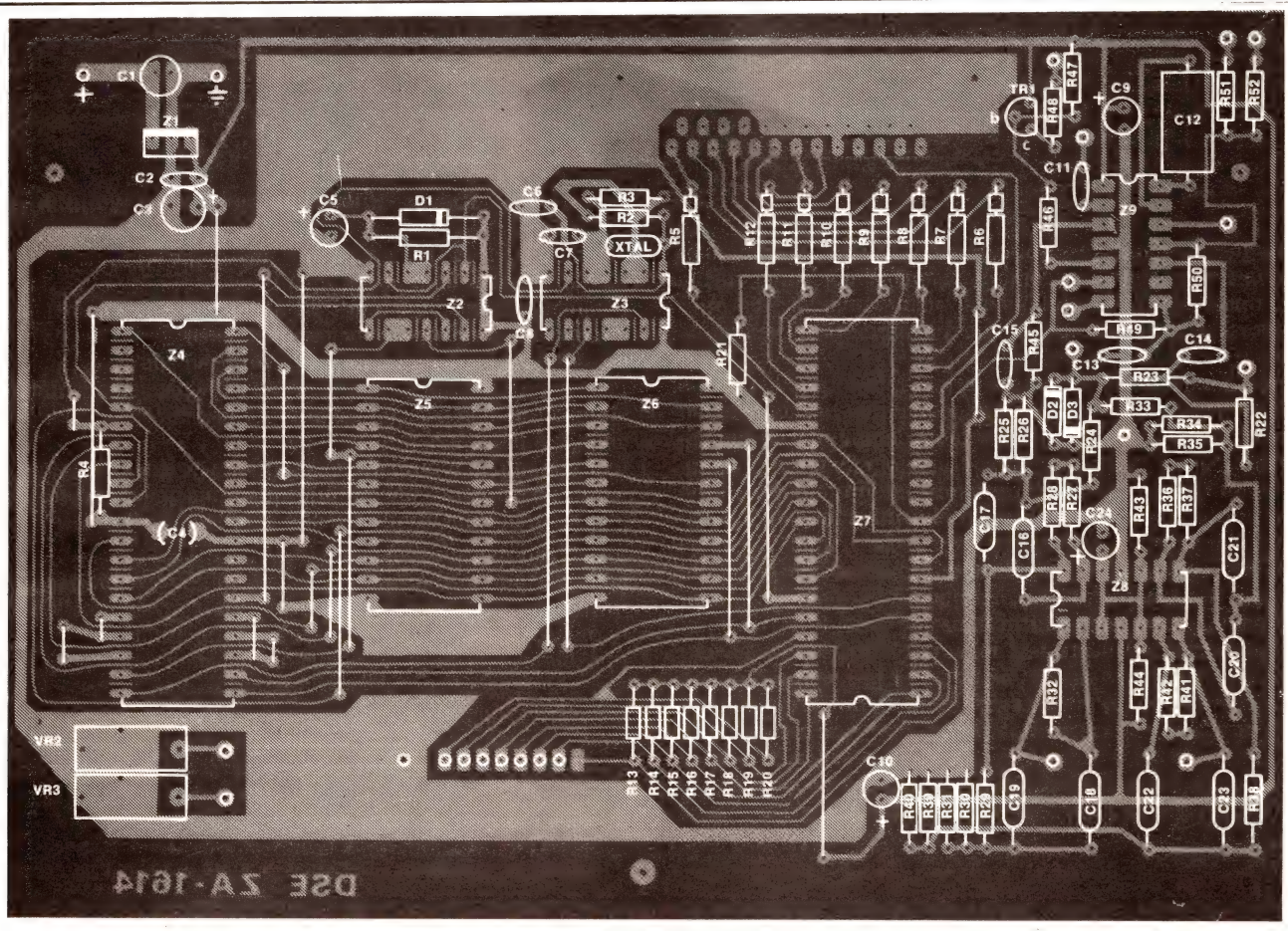
The only remaining circuitry is that for the clock and the power supply. The clock circuit uses a 4 MHz crystal and two sections of a 7404 hex inverter, Z3, configured as an oscillator. A third section of Z3 is used to buffer the clock signal and drives the CPU clock input directly.

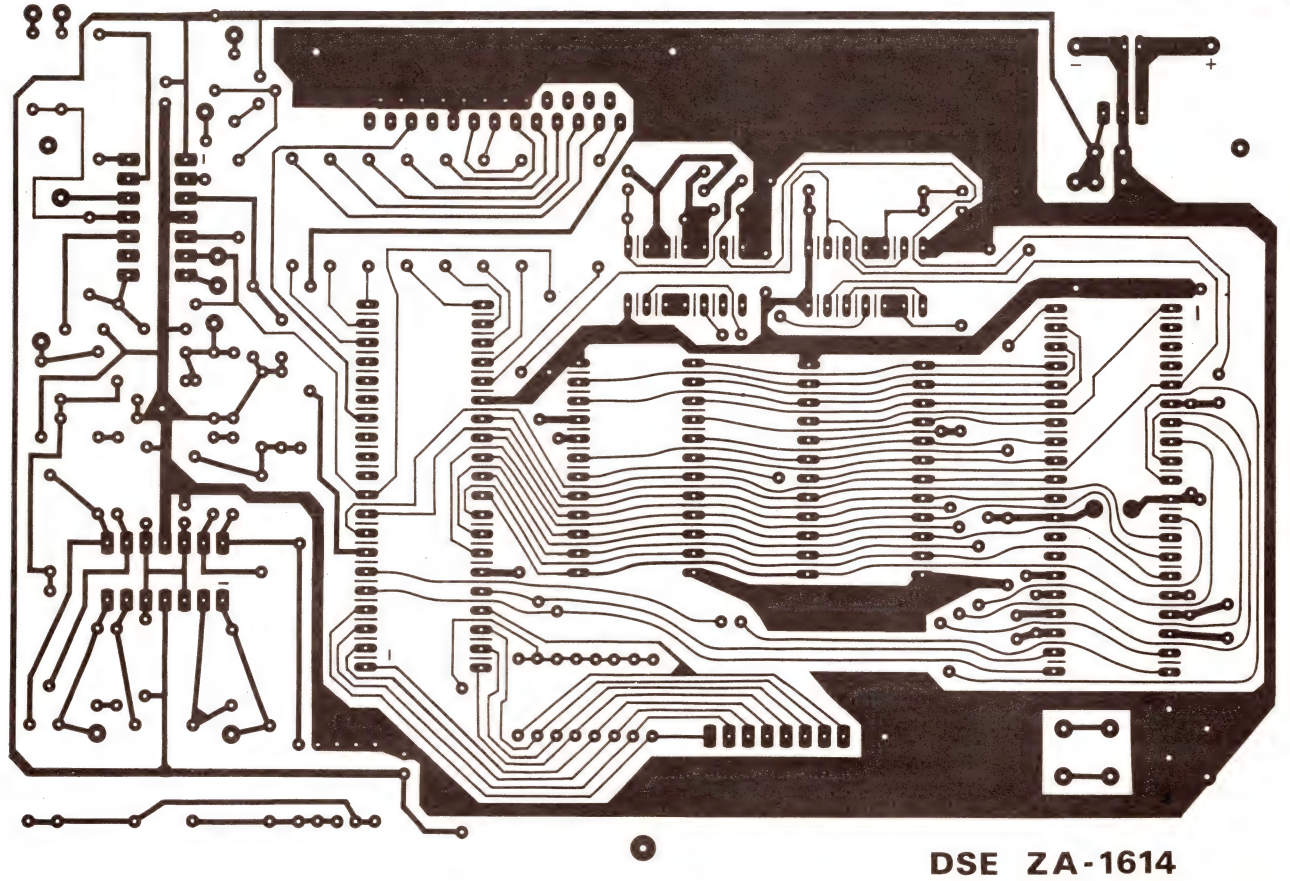
The power for the interface is supplied by a 9 Vdc plugpack. The 9 Vdc is applied to a 7805 three terminal regulator, Z1, which supplies a regulated 5 V to the decoder's circuitry. Two 1k resistors, R44 and R43, are used as a voltage divider to bias the LM324 op-amp, Z8, at half supply for correct operation of the filters.

The software

Upon power up, or when any front panel switch other than SW1 is changed, a carriage return is sent to the printer as an indication that the program is running and the digital section of the decoder is functioning correctly. The software includes provision for a character buffer so that characters are not lost during the printer's carriage returns or printing operations.

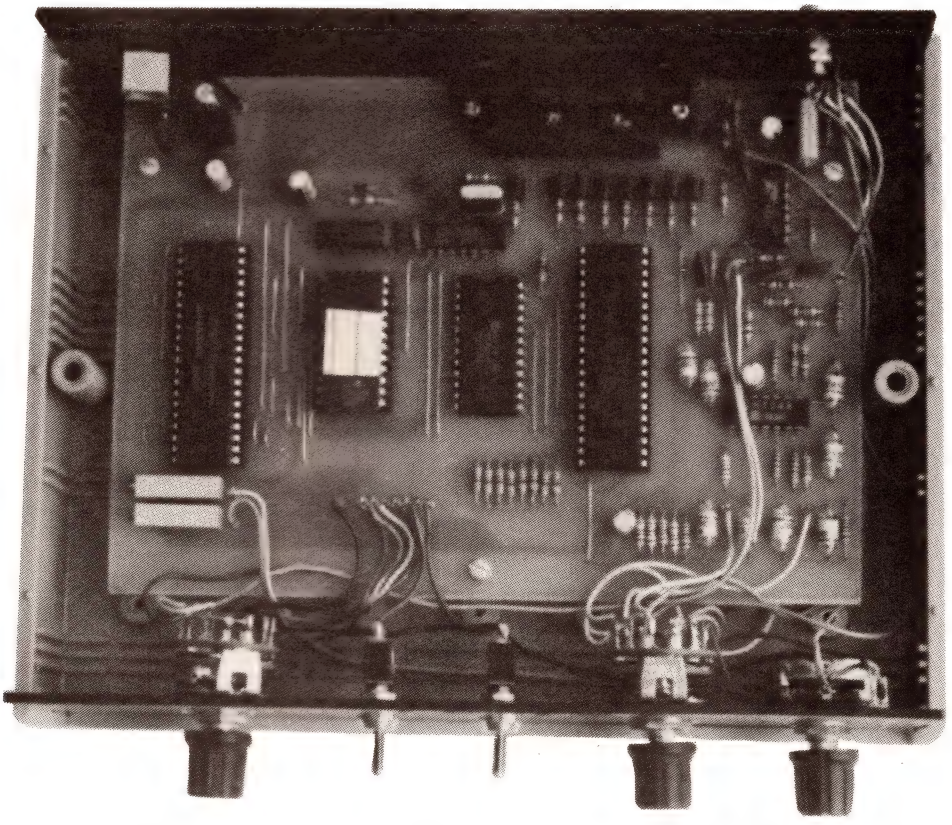
In the Morse decoding and speed tracking process, an image is derived of the average length of a Morse code "DIT" (the 'dot' of the dot-dash code). This is used to monitor the actual transmission speed and to generate the spaces between words, which tend to be between two and three "DAH" (or dash) lengths in duration. The frequency that spaces are inserted between words is a function of the current Morse speed. As the automatic speed tracking is dependent on incoming DIT length, slow Morse speeds will slow the speed tracking process down somewhat, purely because there are less DITs over a given period of time. Rapid Morse speeds will allow the decoder's software to lock on to the transmission speed faster for the same reason.


C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
C17
C18
C19
C20
C21
C22
C23
C24
D1
D2
D3
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
R20
R21
R22
R23
R24
R25
R26
R27
R28
R29
R30
R31
R32
R33
R34
R35
R36
R37
R38
R39
R40
R41
R42
R43
R44
R45
R46
R47
R48
R49
R50
R51
R52
TR1
XTAL
Z1
Z2
Z3
Z4
Z5
Z6
Z7
Z8
Z9
VR2
VR3
DSE ZA-1614



DSE ZA-1614

The printed circuit board screws into the bottom half of the case, access to the RS232 connector being via a cutout in the rear panel. The power supply input connector is located on the rear panel at the left and the audio input jack socket is located on the right.



PARTS LIST
MORSE/RTTY DECODER

Resistors
All ¼ watt, 5% unless noted

R1	47k
R2-R3	220R
R4	1k
R5-R12	10R
R13-R20	4k7
R21	10k
R22	33R
R23	1k
R24	150k metal film 1%
R25-R26	18k " "
R27	180k " "
R28	470k " "
R29	110k " "
R30	18k " "
R31	10k " "
R32	470k " "
R33	270k " "
R34	4k7 " "
R35	24k " "
R36-R37	820k " "
R38	200k " "
R39	18k " "
R40	3k9 " "
R41	120k " "
R42	1M2 " "
R43-R44	1k
R45	470k
R46-R47	4k7
R48	470R
R49	470k
R50	100k
R51	270k
R52	47k
R53	15k
VR1	50k rotary pot
VR2-VR3	10k 10-turn trimpot

Capacitors

C1	10u/25 V RB electro
C2	100n disc ceramic
C3	10u/25 V RB electro
C4	100n disc ceramic
C5	10u/25 V RB electro
C6-C7	100p disc ceramic
C8	100n disc ceramic
C9-C10	10u/25 V RB electro
C11	100n disc ceramic
C12	22n MPC
C13	33n disc ceramic
C14-C15	100n disc ceramic
C16-C23	1n polystyrene 1%
C24	10u/25 V RB electro

Semiconductors

Z1	7805
Z2	74LS132
Z3	7404 (Not "LS")
Z4	Z80 CPU
Z5	2732 EPROM (programmed)
Z6	6116 static RAM
Z7	8255 PPI
Z8	LM324
Z9	XR2211
TR1	BC557/DS557
D1-D3	1N914, 1N4148
D4	small green LED

Miscellaneous

XTAL	4.00 MHz
SW1	4-pole, 3-way rotary switch
SW2	2-pole, 5-way rotary switch
SW3-SW4	SPDT toggle

ZA-1614 pc board; eight ferrite beads; three knobs (DSE H-3850); one cabinet (DSE H-2705) with screened and punched panels; three self tapping screws 3 mm x 12 mm; three 6 mm spacers suit 3 mm screws; one pc board mount DB-25 socket; two M3 x 9 mm bolts; two M3 nuts; two M3 shakeproof/star washers; 400 mm rainbow ribbon cable; 400 mm tinned copper wire; one panel mount 3.5 mm jack socket; one panel mount RCA socket; one plug pack 9 V dc @ 600 mA fitted with 3.5 mm jack plug (DSE M-9560).

Kit price: $159.95

the CPU or printer which may be picked up by the receiver.

When you have fitted all the resistors, you may continue by fitting all the capacitors. Take care with the orientation of the electrolytic types and note that the 100n (0.1 uF) capacitor C4 is mounted on the copper side of the board between the CPU power supply rails. This is done to ensure that the leads of C4 are a minimum length.

Construction can continue with the fitting of the trimpots and the DB25 socket. Once these are installed, you can solder all the semiconductors to the board. Take particular care with the orientation of the ICs as they do not all face in the same direction. Sockets may be used for the CPU, PPI, RAM and ROM chips if desired. It is a good idea to use a socket for the ROM, even if you don't use sockets for the other chips. This will facilitate fitting new or updated ROM chips for possible future software enhancements.

The pc board assembly can now be finished off by fitting any remaining components. When soldering the crystal in place, use the minimum heat for a good joint to avoid any damage.

You can now turn your attention to the case assembly and the interconnecting wiring. The kit supplied by Dick Smith Electronics includes pre-punched and screened case panels so it is a simple matter to mount the switches, sockets and LED. If you are not building the project from a kit, you will need to drill the appropriate holes in the case panels in order to mount the various items. ▷

Mounting the various switches and sockets on the panels will allow you to trial fit them in the case together with the assembled pc board. You will then be able to estimate the approximate lengths required for the various interconnecting wires so that a neat job can be made of the wiring. Pay very careful attention to the wiring diagram, especially when wiring the two multi-position rotary switches, as these can be a bit confusing. Don't forget to mount resistor R53 on switch SW1.

Alignment and operation

After you have completed construction and made a thorough check of the wiring and soldering, you can connect the plug-pack and apply power to the decoder. Special care should be taken when wiring the 3.5 mm jack plug and socket for the power supply as no protection diode has been included in the design. The tip of the plug on the plug pack cable should be connected to the positive side and the corresponding terminal of the panel mounted socket on the decoder should be wired to the "+" pad, nearest the corner of the pc board. If you wish, a 1N4002 diode could be inserted in the flying lead from the positive side of the panel socket for protection. Connect the anode to the socket and the cathode to the "+" pad on the pc board.

When power is applied, the +5 V on-board supply should be checked by measuring at the output terminal of the 7805 regulator. If the +5 V checks out, disconnect the power and connect the decoder to a parallel printer. The decoder is designed to use a standard "IBM" type of printer cable which is fitted with a DB25 plug on one end and a standard "Centronics" style 36-way plug on the other. These cables are readily available from computer accessory outlets as well as Dick Smith Electronics. Power can now be re-applied to the unit and you should observe a carriage return from the printer. This indicates that the digital section of the decoder is functioning correctly.

Alignment of the analogue section of the decoder involves setting VR2 and VR3 for the centre frequencies of the RTTY 2125/2295 Hz and 2125/2975 Hz modes respectively. There are a number of ways to go about this and the method you choose will depend to some extent on what test equipment you have available.

The most accurate method of aligning the decoder is to make use of an audio signal generator. If you have an audio generator available, connect it to the audio input socket of the decoder and apply a low level signal at exactly 2208 Hz. Set SW1 to the 2125/2295 position and set SW2 to any of the RTTY baud rates. The output of the XR2211 demodulator IC can now be monitored by observing the signal on pin 6 of the chip with a dc voltmeter (5 V range) or an oscilloscope.

The output of the XR2211 can be found at the crystal end of R21, nearest the DB25 socket. Start by turning both VR2 and VR3 fully counter-clockwise. Now adjust VR2 until a change of state is observed from the XR2211. Observing the same test point, ensure that the signal is high (+5 V) when a frequency of 2125 Hz is applied from the signal generator and low (0 V) when a frequency of 2295 Hz is applied. If this is not the case, return to a frequency of 2208 Hz and continue turning VR2 clockwise, until another transition occurs and then repeat the test using the 2125/2295 Hz frequencies from the generator.

The procedure for adjusting VR3 is done in exactly the same manner, except that SW1 is set to the 2125/2975 position and the centre frequency from the signal generator should be 2514 Hz instead of 2208 Hz. When both trimpots have been adjusted, you should go back over the alignment and re-check the results.

If you do not have an audio signal generator available, it is possible to use a good quality RTTY signal to align the unit. If this method is used, it is important that the signal accurately complies with frequency and shift standards. For this reason, it is not a good idea to use signals from an SSB receiver as, whilst the shift will be correct, the receiver tuning can vary the actual frequencies applied to the decoder. A good source of stable and accurate RTTY can often be found on parts of the two metre amateur band. These signals use audio frequency shift keying (AFSK) and are transmitted using FM. Most capital cities now have dedicated RTTY repeaters on the two metre band and these are an excellent source of good signals.

With a good RTTY signal applied to the decoder, you can adjust the trimpots either by observing the output of the XR2211 on an oscilloscope or by examining the output on the printer for errors. It should be noted that most amateur RTTY transmissions use the 170 Hz shift standard and are transmitted at 45.45 baud. To align the wide shift RTTY part of the decoder, a good source of 850 Hz shift RTTY will be needed. This may prove a little difficult as most users of this standard are commercial stations using FSK on the HF bands which require the SSB mode to resolve.

Using your decoder

Operation of the decoder is quite straightforward. In the Morse mode, the tuning control on the front panel is used to tune the decoder into the pitch of the received signal. When correctly tuned, the front panel LED will flash in time with the received DITs and DAHs. Don't expect to get perfect, error free reception of Morse code, as much will depend on the characteristics of the transmitted signal. Morse which is sent by hand does not always adhere to the correct element spacing and even the best decoder will become confused by a sloppy operator.

RTTY reception should initially be tried on strong signals such as those found on the amateur two metre band around 146-147 MHz FM. In this mode, the front panel LED will show "in lock" when correctly tuned, indicating that the received tones are within the range set by SW1. As mentioned before, most amateur RTTY is transmitted using the narrower shift and at 45.45 baud.

Once correct RTTY operation has been verified, you can try the decoder on some signals on the HF bands. A good place to start looking for narrow shift amateur signals in in the 20 metre band between about 14 060 kHz and 14 100 kHz. If you only seem to get garbled text, you could try setting the "invert/normal" switch to the other position or try other baud rates. After becoming familiar with the operation of the decoder, you will quickly be able to estimate the correct settings by the sound of the signal.

If you are attempting to receive commercial RTTY stations, remember that a few of these use some method of encryption to prevent unauthorised eavesdropping. There isn't much you can do about these stations as all settings on the decoder will produce meaningless printouts. For some useful information on where to look for interesting RTTY signals on the HF bands, you could refer to the article "A Guide to non-voice transmissions on shortwave" by Roger Harrison VK2ZTB, which was published in the July 1987 issue of Australian Electronics Monthly.

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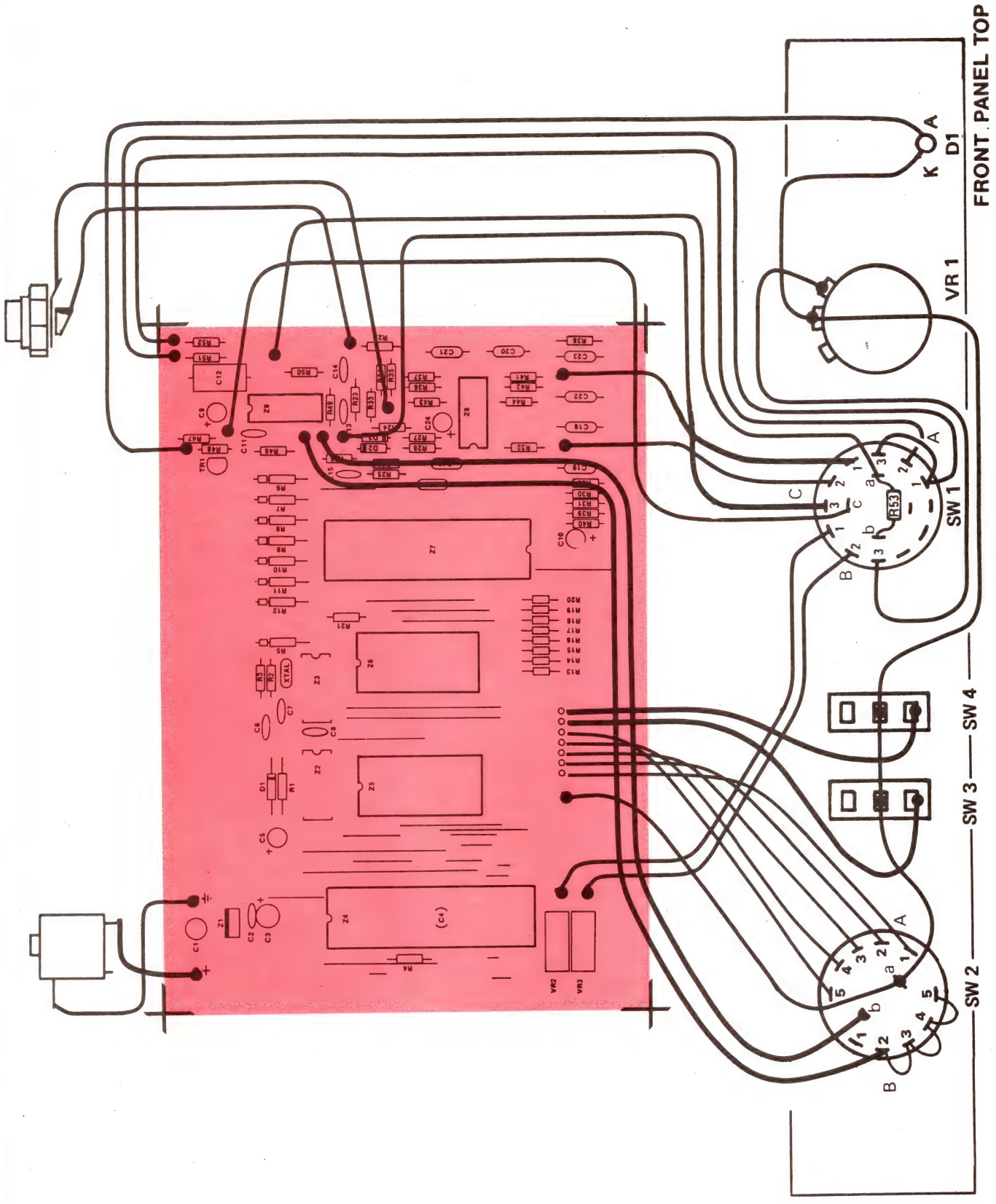
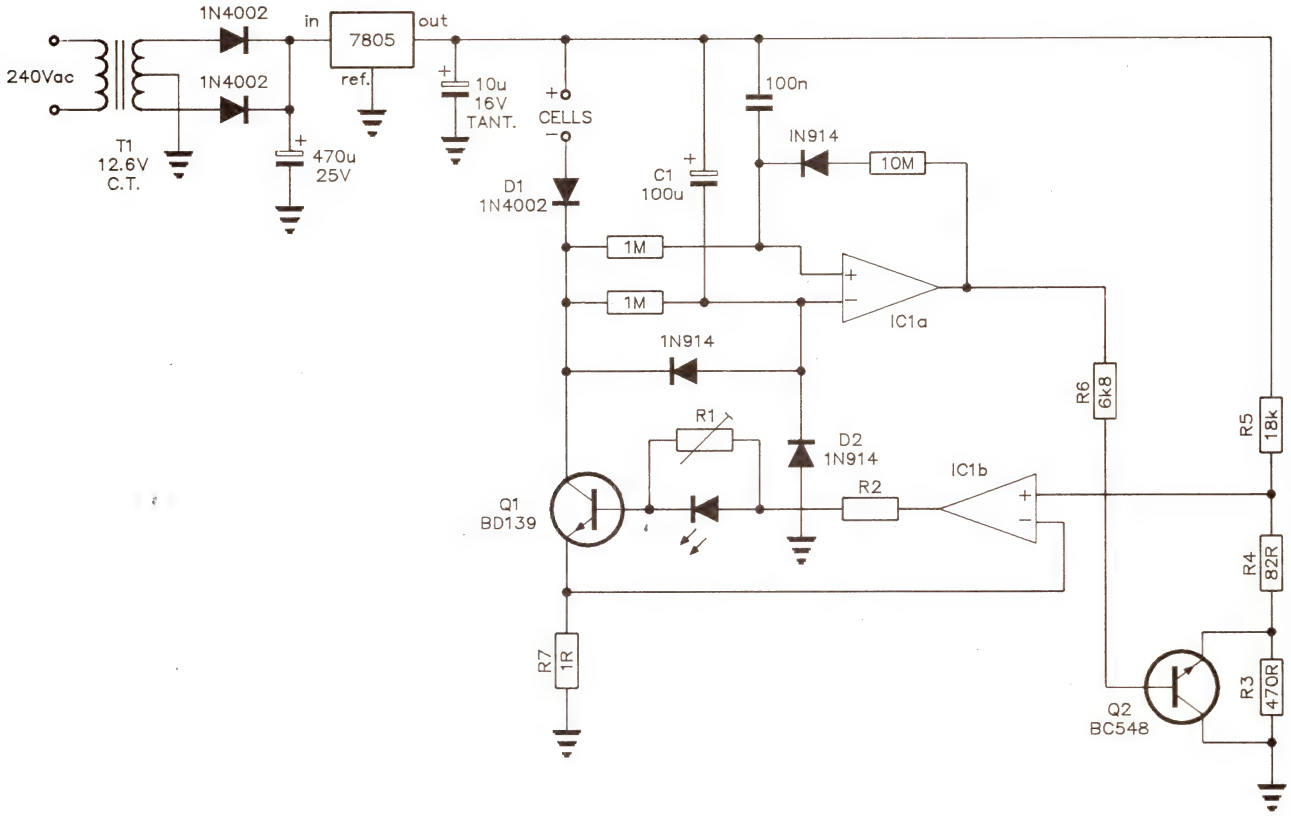

FRONT PANEL TOP
D1
K
A
VR 1
SW 1
SW 4
SW 3
SW 2



An intelligent NiCad charger

Tired of how long it takes for your trickle charger to charge your NiCads?, well this NiCad charger intelligently charges at a reasonable rate and then automatically switches to a trickle charge rate.

Referring to the circuit diagram, the voltage from the RC network on the inverting input of IC1a , an LM358, is higher than and lags the voltage on the non-inverting input. As a consequence, the output of IC1a is low and Q2 is off, allowing the full charge reference voltage from the resistive divider R3-R5 at the non-inverting input of IC1b which is configured as a constant current regulator.

When the cells are fully charged, the voltage at the non-inverting input of IC1a rises above that on the inverting input causing the output to go high. IC1a is configured as a Schmitt trigger so that its output doesn't oscillate between high and low levels when both inputs are near the same voltage.

When the output of IC1a goes high, Q2 turns on, changing the reference voltage to the trickle charge reference voltage. Diode D2 resets IC1a by discharging C1 when the charger is switched off.

Because the charger detects the rise in cell voltage and not a specific voltage, any number of similarly discharged cells can be charged simultaneously up to a limit of about 12. The limit is due to the need for the supply voltage to be higher than the cell, D1, Q1 and R7 voltage drops, but less than the 30 V maximum operating voltage of the LM358, IC1.

If charging only one cell, use two diodes for D1 to keep the inputs of IC1a within their common mode range. The voltage regulator ensures supply fluctuations don't trigger IC1a. The circuit shown is designed to charge two "AA" cells. For charging more, or different capacity cells, change the voltage regulator, supply voltage and current regulator reference voltage resistors R3-R5. Charge rates should be as follows:

Trickle:	1/16 x cell capacity
Full:	3/10 x cell capacity
Fast:	2 x cell capacity.

To set the current settings, replace the cells with an ammeter and switch the charger on. Adjust the value of R4 until the trickle charge rate is correct. Next, short the inverting input of IC1a to ground and adjust R3 to obtain the correct full charge current. Resistors R1 and R2 may be necessary for other cell capacities or charge rates. Resistor R1 is an open circuit and R2 a short circuit for this design.

Resistor R2 sets the maximum current through the LED. When no cells are connected, the output of IC1b is high, consequently, large currents may flow through the LED resulting in it's destruction. R2 should be set so that Q1 can turn on sufficiently to allow the full charge rate when all cells are connected. R1 shares the current with the LED, as large currents may be needed to turn Q1 on sufficiently for the full charge rate. Resistor R6 will need to be increased if a higher supply voltage is used to prevent excessive current through Q2.

Operation of the charger is very simple: turn it off, insert the cells and turn it on. The LED acts as an indicator and will glow very brightly when no cells are connected, brightly when charging and dim when the cells are fully charged.

Daryl Pilkington
Kurralta Park, SA

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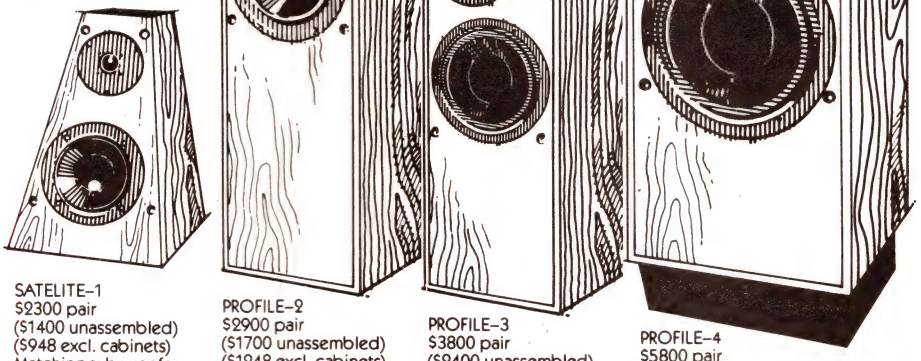

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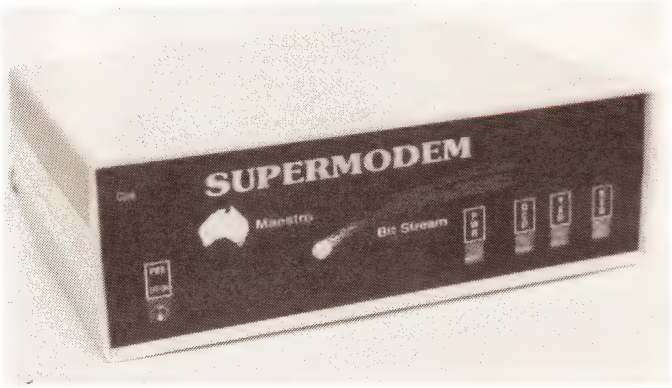

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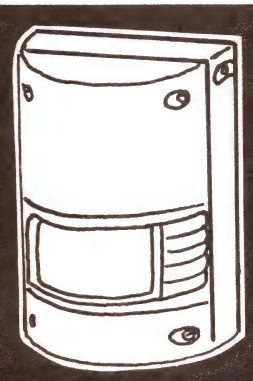

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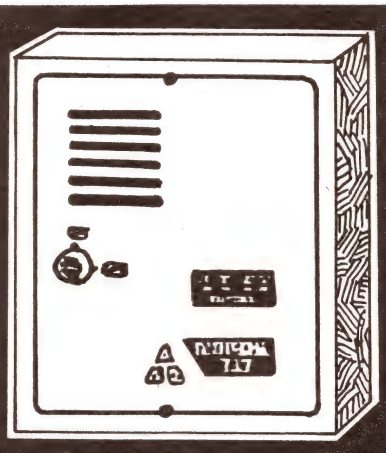

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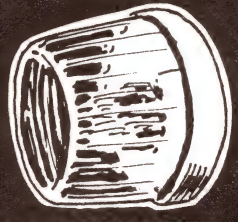

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Sep. '87
Digital Volume Control
Precision Rectifier
Function Generator
Morse Filters
Wien Bridge Oscillator
Precision Crystal Oscillator
Limiter for Guitars
Serial Data Converter
High Level Wideband RF Preamplifier
Pierce Oscillator
Buzzer Driver
Current Corrected AF Amplifier
Current Indicator for 723 Regulator
Digital Audio Selector
Patch Catcher

Oct. '87
Battery-Backed RAM Module for the C64
Build a Horn Loaded Loudspeaker
Active Crossover

Nov. '87
IEC-Centronics Interface
Low-noise Mic Preamp
SSB Adaptor

Dec. '87
Long-Range Infra-Red Transmitter-Receiver
SSB Receiver for 20 and 80 Metres
Dimmer for Inductive Loads

– AEM4000 SuperMicro, from page 23.

5-7 MIPS (with a corresponding crystal change), and 55 ns SRAMs will bring out the full speed of the board. Fast SRAMS, however, are hellishly expensive at the moment, so the optimum cost-to-benefit ratio mandates the use of 120 ns SRAMs. Faster versions are available from the designers of the board, on request (POA).

The large blank area at the top right is reserved for future expansion and will probably be used for a very fancy on-board A/D converter.

The remainder of the circuit is mainly devoted to "glue" chips, used to drive and decode signals to and from the Novix. A complete description of circuit operation will be provided in a subsequent issue.

Constructors should note the use of a large number of 74Fxxx devices on the board. These are extremely fast versions of the standard LS series of chips. PLEASE NOTE that LS series chips are not interchangeable with these. ALthough they are pin compatible, the LS series are just not fast enough to allow the board to operate at the high speeds required to deliver up to 8 MIPS.

Next month I will commence with details of the actual construction of the board.

FOOLPROOF GATE ARRAY 8000 GATES FROM XILINX, THE PROGRAMMABLE GATE ARRAY COMPANY

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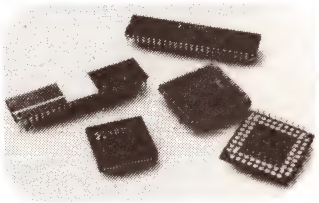
• Fully user-programmable functions: – I/O functions – digital logic functions – interconnections • General-purpose array architecture • Complete user control of design cycle • Compatible arrays with logic cell complexity equivalent to 1200 and 1800 usable gates • Standard product availibility • 100% factory-tested • Selectable configuration modes • Low-power, CMOS, static memory technology • Three performance options: 33 MHz, 50 MHz, 70 MHz • TTL or CMOS input thresholds



• Complete development system support: – XACT Design Editor – Schematic Entry – XACTOR in-circuit Emulator – Macro library – Timing Calculator – Logic & timing simulator – Auto place/route.

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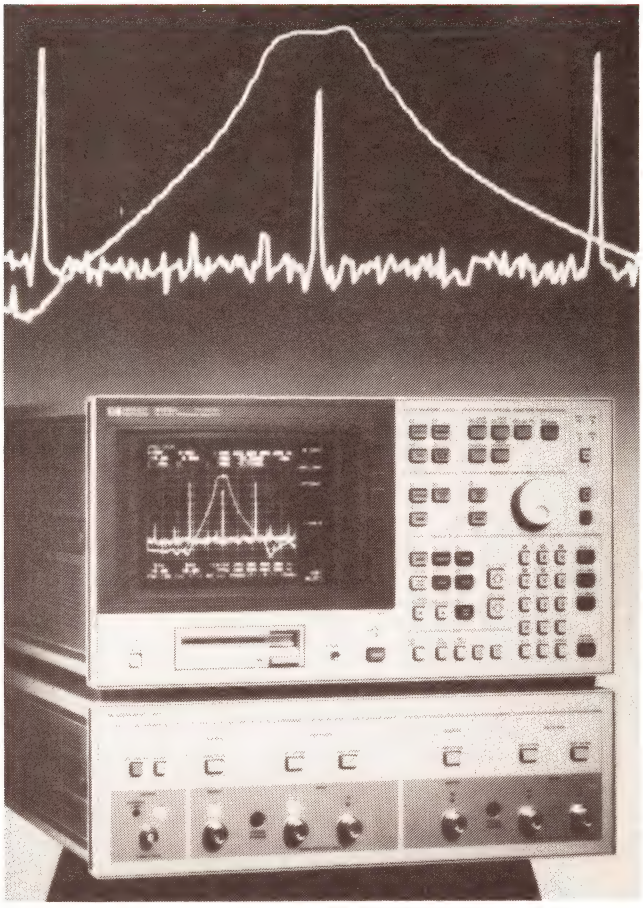


New analyser from HP

The new HP 4195A network/spectrum analyser is the first instrument from Hewlett-Packard that provides vector network and spectrum measurements in one unit. Covering 10 Hz to 500 MHz, the new instrument is designed for engineers who develop and test analogue circuits and components used in communication, telecommunication, consumer and computer peripheral equipment.

The HP 4195A has a colour graphics CRT and provides rectangular, tabular, Smith and polar display formats for convenient viewing of measurement data.

For improved measurement efficiency, the analyser has a built-in 3.5" disk drive for storing and retrieving all instrument control settings, measurement data, program-points table (for sweeps) and user programs (for executing custom functions).

The analyser's multichannel measurement port configuration allows it to be used in a wide range of applications for linear and non-linear device measurements. It has two channels, each consisting of one output and two input ports.

The HP 4195A also performs multichannel spectrum measurements. Its four input ports can perform spectrum measurements, allowing for multiple connections to a device without moving a test probe.

For further information, contact Hewlett-Packard Customer Information Centre on their toll-free number: **008 033 821.**

New release for AutoCAD

Autodesk Australia Pty Ltd has announced the pending release of a new AutoCAD product. To be called Release 9 (this is the ninth major enhancement of AutoCAD), the new product features an advanced user interface with pull-down menus, icon menus and dialogue boxes that supplement the keyboard, screen menu and digitizer template as a means of entering commands.

AutoCAD Release 9 offers a significant advance in supporting AutoCAD in a network environment with the addition of AutoCAD file portability.

The files AutoCAD creates can now be accessed by any supported operating system. PC-DOS/MS-DOS. Apollo's AEGIS, Digital Equipment's VMS and Sun Microsystem's UNIX are all supported.

Files created under any of these systems will be recognised by any computer running AutoCAD. There will no longer be a need to convert them first to an intermediate format like DXF or IGES.

AutoCAD Release 9 will be distributed only through Authorised AutoCAD Dealers and has a suggested retail price of $4800.00 excluding sales tax. Various upgrade paths from existing versions can be made at a nominal cost and these can be confirmed by consulting an Authorised AutoCAD Dealer.

Further information is available from: **Autodesk Australia, 9 Clifton Street, Richmond 3121 Vic. (03)429 9888.**

Safety banana plugs

Radiall has introduced a series of safety banana plugs developed to provide you with maximum protection when handling live connections.

A spring-loaded shroud covers the plug pin and the tip of the pin itself is insulated to ensure that at all times during normal use it is impossible to touch the live conductor.

The series comprises of all 4 mm stackable plugs, standard patch leads and test prod leads. Two versions have been developed, fixed shroud for use with safety type sockets and a spring-loaded retractable shroud types for use on stackable plugs and leads.

Applications include educational, medical, laboratory, test equipment and servicing. For further information, contact: **A. P. Imports, 41 Box Road, Crossroads 2170 NSW. (02)600 9722.**

New modem means business

A new four-speed modem, the Maxwell-5, recently released by ABE Computers of Melbourne, is ideal for engineers, students and enthusiasts alike who need reliable, business-like data communications at a variety of speeds and standards and at an affordable price, according to proprietor, Max Elliot.

ABE's new modem provides four communications speeds of 2400 bps full duplex, 1200 bps full duplex, 1200/75 bps half duplex (and reverse) and 300 bps full duplex.

Both CCITT and Bell tone standards may be used, making the unit compatible with both local and overseas standards.

The Maxwell-5 features the "AT" (Hayes-compatible) command set, auto-dial/auto-answer, auto speed selection and auto test facilities.

Both tone and pulse dialling is available (software selectable) and the modem sports ten 16-digit memories for storing often-used numbers. The memory is battery-backed so that you don't have to go to the tedium of reprogramming it should the power fail or be accidentally disconnected for some reason.

The Maxwell-5 includes 10 LED status indicators on its front panel and an inbuilt speaker for call progress monitoring.

The unit is ideal for applications in automated data logging, automated downloading/uploading to and from remote data bases, remote bulletin use as well as general data communications.

At $790.00 inc. tax, it costs about what you might have paid for a number of three-speed modems in recent times.

Contact **ABE computers, 24 Burwood Hwy (Rd), Burwood 3125 Vic. (03)288 2144, 288 9076. Or fax Max on (03)288 0781.**

Practical filter design — without fears or tears

Jack Middlehurst

Part 4 – Elliptic filters

Here we make a close encounter with "the elliptic integral of the first kind", and may closely approach a "brick wall". Could be fun!

BEFORE we get to our next major filter, it will pay us to take a look at another type of simple filter. This is the *notch filter* having the circuit of Figure 4.1a. If you are not familiar with this circuit, it can contain some surprises. As an example, let us do some measurements on such a circuit with L = 100 mH, C = 0.2533 uF and R = 300 Ohms, and the resistance of the inductor equal to zero. We apply a signal generator (having an output impedance of 1 Ohm or less) to the input terminals and measure (with a high impedance meter or CRO) the RMS voltages across L, C, and the output terminals. If we keep the input voltage constant at 1 V RMS and vary the frequency, we find that, at below 1000 Hz, the voltage across the capacitor is larger than that across the inductor, whereas above 1000 Hz the reverse is the case.

At 1000 Hz (the resonant frequency of the circuit) the voltages across the inductor and the capacitor are both 2.09 V RMS. This is because the values chosen give the circuit a Q of 2.09. However, the voltage across the output terminals is not 2.09 + 2.09 V RMS as you might have supposed, but is, in fact, zero.

Figure 4.2 shows why this happens. We are now looking at the instantaneous voltages, not the RMS voltages and you can see that, at the resonant frequency, the voltage across the capacitor leads the input voltage by a quarter of a wavelength (90 degrees), while the voltage across the inductor lags the input voltage by 90 degrees. So there is a difference of 180 degrees between the voltages across the inductor and capacitor. This means that, if at any instant the voltage across the inductor is V volts, the voltage across the capacitor is –V volts. So when you add the two together at any time, you always get zero. If the inductor itself has a resistance, the voltages across the inductor and capacitor are not 180 degrees out of phase, so the RMS output voltage does not go to zero at any stage; at resonance, the output voltage simply drops to a minimum.

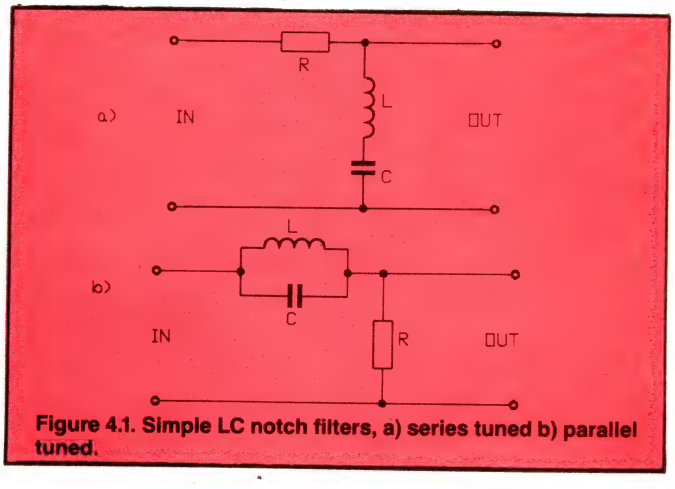


Figure 4.1. Simple LC notch filters, a) series tuned b) parallel tuned.

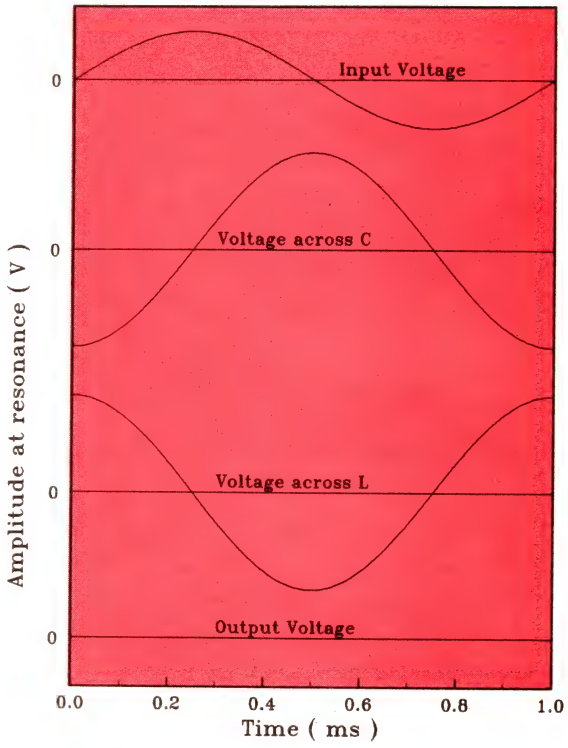


Figure 4.2. Waveforms measured on the circuit of Figure 4.1a

Figure 4.3 shows the frequency response of this circuit for different values of Q. As the Q is made higher, the notch gets sharper. The frequency response of such a filter looks symmetrical only if the frequency is plotted on a logarithmic scale as is done in this Figure. Low Q notch filters of this kind are rarely used for audio work since they introduce significant attenuation a long way from the frequency they are designed to remove. However, such simple filters are sometimes used in RF work to eliminate annoying frequencies. A similar frequency response is obtained using the filter of Figure 4.1b. We will be looking in detail at notch filters of various kinds later.

The reason for introducing the simple notch filter at this stage is because of the way it can be used to increase the sharpness of cutoff of other types of filter. In the search for filters with ever sharper cutoffs, the effect of adding notch filters to Butterworth designs was much studied in the 1920s.

Figure 4.4 shows the frequency response of a 3rd order Butterworth filter with and without a notch filter having a Q of 10. Clearly the slope of the attenuation curve near the cutoff frequency is greatly improved when you add the notch, and the attenuation is always more than that of the Butterworth alone.

Two additional things are worth noticing about this frequency response. Firstly the actual cutoff frequency (where the attenuation is 3 dB) has been changed from its design value. This means that the addition of a notch changes the design formulae for the rest of the filter if the cutoff frequency is to remain the same. Secondly, in all previous LP filters that we have dis-

cussed, the attenuation in the stopband has increased continuously as the frequency has been increased: in this form of filter it does not. You can see that, after dipping very sharply after the cutoff, the attenuation actually gets less, rising to about 12 dB at about 410 Hz, and then increasing again.

This raises the whole question of the efficiency of filters in terms of the number of components that they require for a given performance. This is not of much concern for the occasional user, but if you have to make thousands of filters, as telecommunications companies do, it becomes the paramount consideration. So the question is "do we really need an attenuation that continues towards an infinite value in the stopband ?" For example, a 7th order Chebychev LP filter with a cutoff frequency of 20 kHz and a passband ripple of 1 dB has an attenuation of 70 dB by 40 kHz, over 160 dB by 200 kHz, and so on. If we have a desired signal of 1 V and a massive interfering signal at 200 kHz of 10 V, this filter would reduce the 200 kHz signal to 0.1 microvolt! This is certainly overdoing things. For most filters with this cutoff frequency, we would probably be quite content to settle for an attenuation of 70 dB for all frequencies above 40 kHz.

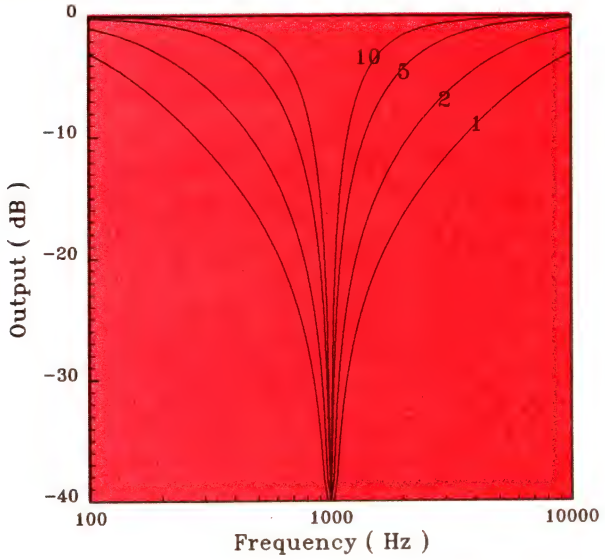


Figure 4.3. Frequency response of simple notch filters such as those in Figure 4.1. Curves are shown for circuits having Qs of 1, 2, 5, and 10.

Elliptic filters

The general idea in trying to find more efficient filters was to use the technique shown in Figure 4.4 but with several notches, each making a hole where their neighbour had a minimum attenuation, e.g: putting another notch at 410 Hz in the filter of Figure 4.5, and so on. This seems to be adding more components, not using less as we has hoped. This whole problem occupied many engineers and network theorists for years and led to a number of interesting designs of filters.

In 1931 a specialist in network analysis, Professor Wilhelm Cauer, was able to show that optimum steepness, just after the cutoff frequency, is achieved if you have a filter which is equiripple in the passband and also equiripple in the stopband. This latter simply means that the tops of all the peaks in the stopband have to reach the same level of attenuation. Such filters are known as Cauer filters or, more commonly, elliptic filters. The reason for this last name is that their design is based on the mathematical properties of the elliptic integral of the first kind.

Because of their importance, and the difficulty of calculating the values of their components, many engineering filter textbooks and cookbooks contain extensive tables that enable you to design a range of elliptic filters. As well as the ripple in

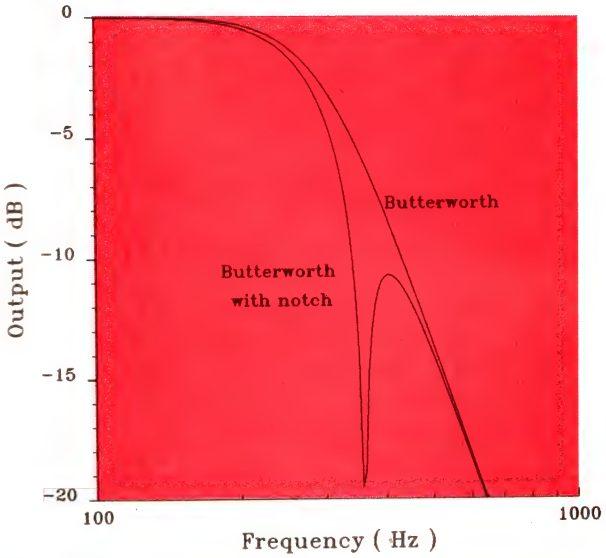


Figure 4.4. Frequency response of a 3rd order Butterworth filter with and without the addition of a notch filter showing the increased sharpness of cutoff achieved by adding the notch.

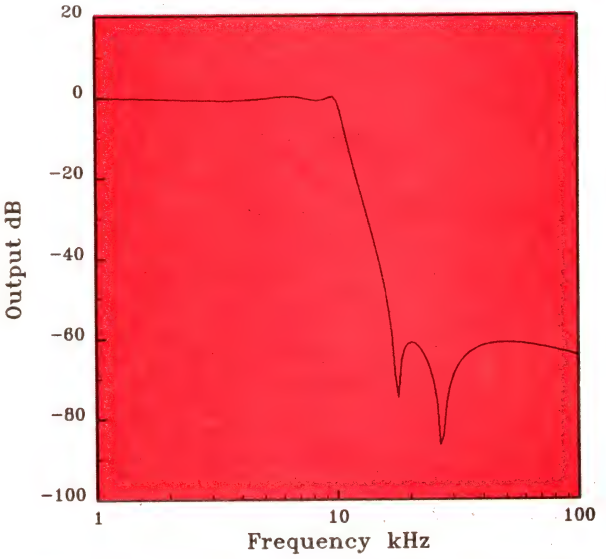


Figure 4.5. Frequency response of a 5th order Elliptic filter having a cutoff frequency of 10 kHz, 1 dB ripple and a minimum attenuation of 60 dB in the stopband.

the passband, elliptic filters give the designer an additional variable to play with. This means that there is an enormous number of combinations from which to choose and such tables can run to hundreds of pages. Rather than simplifying things, this tends to be quite confusing on first acquaintance, so many enthusiasts simply turn away from elliptic filters and put them in the too hard basket. However, as we will see, they are both simpler and cheaper than Butterworth and Chebychev filters for a given sharpness of cutoff.

It is interesting at this stage to compare the order of Butterworth, Chebychev, and Elliptic filters needed to achieve any required attenuation with an LP filter. For example, to have a cutoff frequency of 10 kHz, a passband ripple of 1 dB and an attenuation of at least 60 dB from 17 kHz onwards, you would need a Butterworth filter of order 14, a Chebychev of order 8, or an elliptic filter of order only 5. In addition, the Qs of the tuned circuits of elliptic filters are less than those of Chebychev filters having the same cutoff rate. So you can see why so much effort was put into developing elliptic filters.

Figure 4.5 is the frequency response of the elliptic filter men-

tioned in the paragraph above. This is the general form of the frequency response of 5th order LP elliptic filters. It is a bit hard to see the equiripple response in the passband since the ripple is only 1 dB, but it has exactly the same shape as that for a 5th order Chebychev filter. However, the form of the attenuation in the stopband is clear. Notice particularly that the tops of the two peaks in the stopband are both at −60 dB.

With this type of filter the passband is defined in the usual way, except that the cutoff frequency is where the response is down by the ripple amplitude, not 3 dB. In addition, the stopband is defined as commencing where the attenuation first reaches the same value as the tops of the attenuation minima, in this case −60 dB. So for this particular filter, the stopband commences at 17 kHz.

The stopband continues to infinity for LP filters, or zero frequency for HP filters. The intermediate frequency range between the passband edge and the stopband edge is called the transition region or transition band, so for the above filter the transition band is from 10 kHz to 17 kHz. For higher order filters there are more notches in the stopband; e.g: there are 3 for a 7th order filter.

For bandpass filters the frequency response is similar to that shown in Figure 4.5 with a mirror image on the left hand side, so a 5th order BP filter would have four notches, two below the lower cutoff frequency and two above the upper cutoff frequency. The frequencies of the lower notches are mathematically related to those of the upper notches, so it is not possible to tune them independently. The centre frequency of the bandpass filter would not be zero but some higher frequency such that the whole of the passband is above zero frequency. Elliptic band reject filters have all their notches in the stop band.

Elliptic filter circuits

Figure 4.6 shows the circuits of a 5th and a 6th order elliptic LP filter, together with their duals. These differ from previous filter circuits in two important ways. Firstly, the filter order is not equal to the number of frequency sensitive components. By comparing these circuits with those of Figure 2.1 in the second part of this series, you can see how a 5th order elliptic filter is simply derived from a 5th order Butterworth or Chebychev filter. For simplicity, they are all given the same order. Secondly, this is the first LP filter in which parallel or series tuned circuits are used. In the normal filter these perform the function of generating the notches in the frequency response. The reason for showing both 5th and 6th order filters is to emphasise the differences that exist between odd and even order elliptic filters. The final section in the even order normal filter is not quite what one would have expected, being a simple inductor rather than a tuned circuit.

Duals are particularly important in elliptic filter designs as we shall see when considering HP filters. In fact all filter tables give the circuits of both the normal circuit and the dual, the former at the top of each table and the latter at the bottom. To reduce the number of inductors, it is the dual of the LP filter rather that the normal LP filter that is transformed into an HP filter. To transform an elliptic LP filter to an HP filter, the Ls are converted into Cs and vice versa in the same way as for Butterworth or Chebychev filters. The result for 5th and 6th order filters is shown in Figure 4.7.

Figure 4.8 shows the way in which the LP circuit is transformed into BP, and BR filters. The additional section required to convert a 5th order to a 6th order is shown on the right hand side of the Figure. For BP filters, each shunt capacitor is parallel resonated with an inductor and each notch filter is split into two, one above the centre frequency and one below it, both being within the stopband. For the BR filter, each shunt capacitor is series resonated with an inductor and again each notch filter is split into two, symmetrically placed about the centre frequency and within the rejection band. Particular care

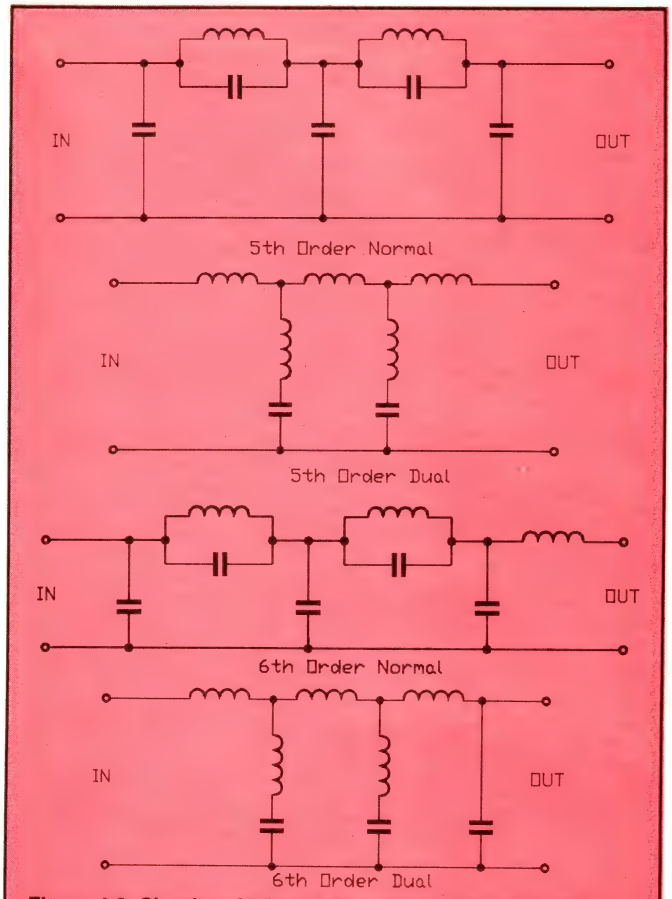


Figure 4.6. Circuits of 5th and 6th order LC Elliptic LP filters and their duals. Note particularly the unexpected nature of the extra section in the even order filter.

has to be taken with even order BP and BR filters because of the way in which the last section differs from those of odd order filters.

Use of the tables

While it is possible to use a desktop computer to calculate the frequencies to which to tune the circuits in an elliptic filter, the programs to calculate the values of the components are rather large and complex. This is because, at several stages in the synthesis of the filter, considerable judgment must be exercised by the program, based on previous experience, in the choice of the mathematical procedure to be used.

Such programs have been developed by the engineers at, for example, Bell Telephone Laboratories, but they are not the kind

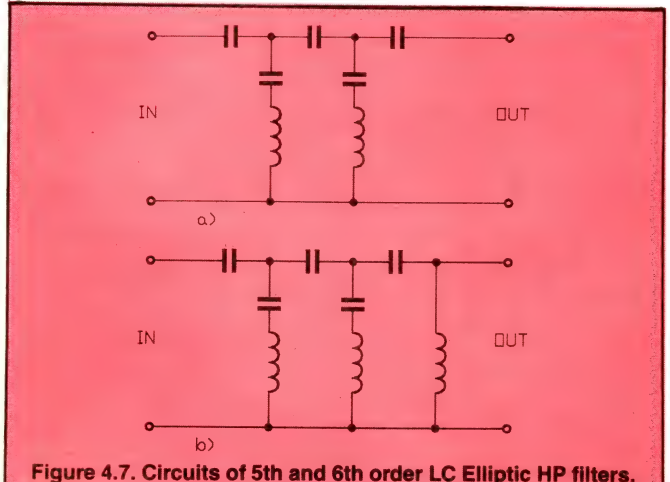


Figure 4.7. Circuits of 5th and 6th order LC Elliptic HP filters.

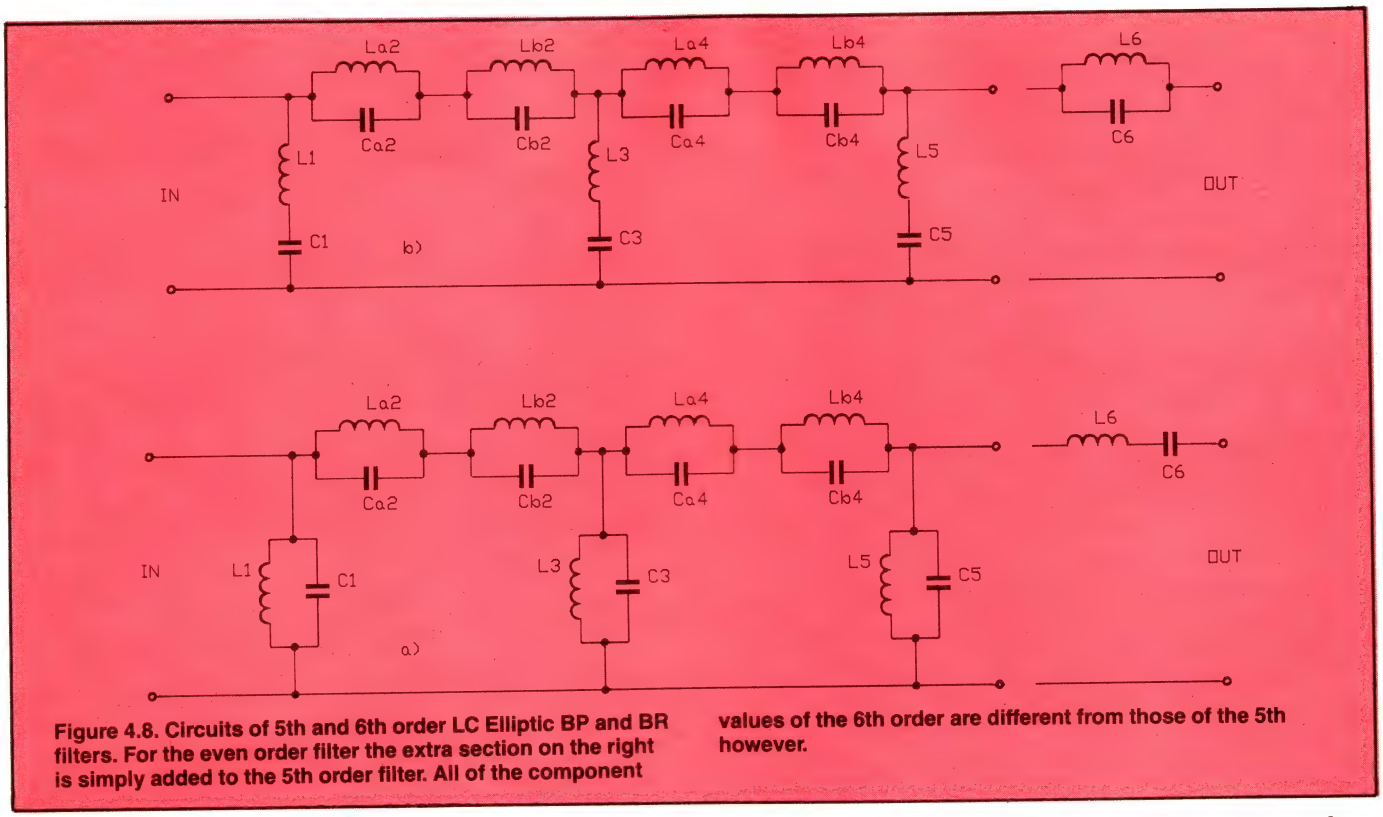


Figure 4.8. Circuits of 5th and 6th order LC Elliptic BP and BR filters. For the even order filter the extra section on the right is simply added to the 5th order filter. All of the component values of the 6th order are different from those of the 5th however.

of thing that you would want to type into your computer. To save the enormous amount of (error prone !) work that this involves, extensive tables of elliptic filters have been calculated and are available in Zverev's and William's books, for example. These tables are for normalized (Rsource = 1 Ohm, Frequency = 1 radian/sec) LP filters and they are designed for filters that use the minimum number of inductors. There remains the problem of denormalizing the tabled values into practical units. Then the LP values have to be converted into suitable values for HP, BP, and BR filters if you need one of these. This is not a trivial matter unless your arithmetic is extremely reliable, so we will use a computer program to do all this for us.

To be able to use the tables, it is necessary to understand the conventions that are used in describing elliptic filters. Normalized LP elliptic filters are given a number such as C 05 20 30. The C stands for Cauer (in honour of his extensive work on them), the 05 is the filter order, the 20 is the value of the reflection coefficient, the 30 is the value of the modular angle. The meanings of these last two properties are explained in the next two paragraphs.

		C 03 05		NORMAL		
MA	Fratio	Amin	C1=C3	C2	L2	W2
6	9.5668	56.85	0.6336	0.0085	0.9676	11.0392
7	8.2055	52.82	0.6314	0.0116	0.9636	9.4661
8	7.1853	49.33	0.6289	0.0152	0.9589	8.2868
9	6.3925	46.25	0.6261	0.0193	0.9536	7.3700
10	5.7588	43.49	0.6229	0.0240	0.9477	6.6370
11	5.2408	41.00	0.6194	0.0291	0.9411	6.0377
12	4.8097	38.71	0.6155	0.0349	0.9339	5.5386
13	4.4454	36.61	0.6113	0.0412	0.9261	5.1166
14	4.1336	34.66	0.6068	0.0482	0.9177	4.7552
15	3.8637	32.85	0.6020	0.0558	0.9087	4.4423
16	3.6280	31.14	0.5968	0.0640	0.8991	4.1688
17	3.4203	29.54	0.5913	0.0729	0.8888	3.9277
18	3.2361	28.03	0.5855	0.0826	0.8780	3.7137
19	3.0716	26.60	0.5793	0.0930	0.8665	3.5224
20	2.9238	25.24	0.5728	0.1043	0.8545	3.3505
21	2.7904	23.95	0.5661	0.1164	0.8418	3.1951
22	2.6695	22.71	0.5590	0.1294	0.8286	3.0541
23	2.5593	21.53	0.5515	0.1434	0.8148	2.9256
24	2.4586	20.40	0.5438	0.1585	0.8004	2.8079
25	2.3662	19.31	0.5358	0.1747	0.7855	2.6999
26	2.2812	18.27	0.5275	0.1921	0.7700	2.6003
27	2.2027	17.26	0.5189	0.2108	0.7540	2.5083
28	2.1301	16.30	0.5100	0.2309	0.7375	2.4231
29	2.0627	15.37	0.5009	0.2526	0.7205	2.3484
30	2.0000	14.47	0.4915	0.2760	0.7031	2.2701
MA	Fratio	Amin	L1=L3	L2	C2	W2
		C 03 20		DUAL		

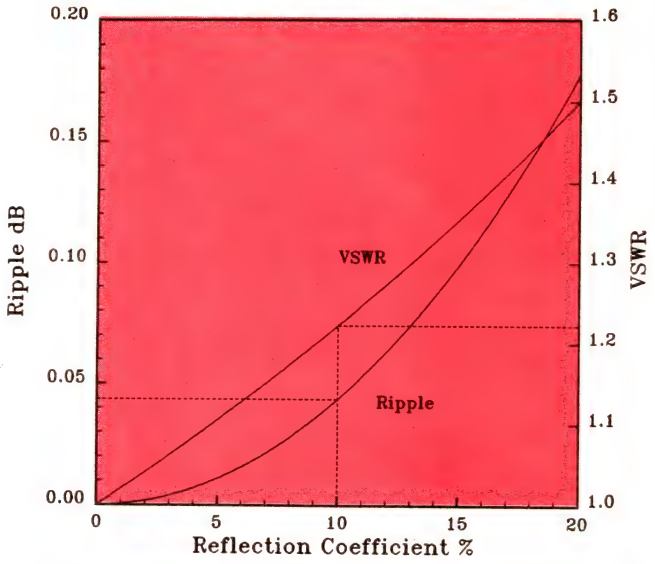
Adapted from A.I.Zverev " Handbook of Filter Synthesis " John Wiley & Sons NY 1967

		C 03 20		NORMAL		
MA	Fratio	Amin	C1=C3	C2	L2	W2
6	9.5668	69.05	1.1839	0.0072	1.1464	11 0392
7	8.2055	65.03	1.1819	0.0098	1.1436	9.4661
8	7.1853	61.54	1.1796	0.0128	1.1404	8.2868
9	6.3925	58.46	1.1770	0.0162	1.1367	7.3700
10	5.7588	55.70	1.1740	0.0200	1.1326	6.6370
11	5.2408	53.20	1.1708	0.0243	1.1281	6.0377
12	4.8097	50.92	1.1672	0.0290	1.1231	5.5386
13	4.4454	48.82	1.1634	0.0342	1.1177	5.1166
14	4.1336	46.87	1.1592	0.0398	1.1119	4.7552
15	3.8637	45.05	1.1547	0.0458	1.1057	4.4423
16	3.6280	43.35	1.1500	0.0524	1.0990	4.1688
17	3.4203	41.75	1.1449	0.0594	1.0919	3.9277
18	3.2361	40.23	1.1395	0.0669	1.0844	3.7137
19	3.0716	38.80	1.1338	0.0749	1.0764	3.5224
20	2.9238	37.44	1.1278	0.0834	1.0681	3.3505
21	2.7904	36.14	1.1215	0.0925	1.0593	3.1951
22	2.6695	34.90	1.1149	0.1021	1.0500	3.0541
23	2.5593	33.71	1.1080	0.1123	1.0404	2.9256
24	2.4586	32.57	1.1008	0.1231	1.0303	2.8079
25	2.3662	31.47	1.0933	0.1345	1.0199	2.6999
26	2.2812	30.41	1.0855	0.1466	1.0090	2.6003
27	2.2027	29.39	1.0773	0.1593	0.9976	2.5083
28	2.1301	28.41	1.0689	0.1728	0.9859	2.4231
29	2.0627	27.45	1.0602	0.1869	0.9738	2.3484
30	2.0000	26.53	1.0512	0.2019	0.9612	2.2701
31	1.9416	25.63	1.0420	0.2176	0.9483	2.2012
32	1.8871	24.76	1.0324	0.2343	0.9349	2.1368
33	1.8361	23.92	1.0225	0.2518	0.9212	2.0765
34	1.7883	23.09	1.0123	0.2702	0.9070	2.0199
35	1.7434	22.29	1.0019	0.2897	0.8925	1.9666
36	1.7013	21.51	0.9912	0.3103	0.8776	1.9165
37	1.6616	20.74	0.9802	0.3320	0.8623	1.8692
38	1.6243	20.00	0.9689	0.3549	0.8466	1.8245
39	1.5890	19.27	0.9573	0.3791	0.8305	1.7823
40	1.5557	18.56	0.9455	0.4047	0.8141	1.7423
41	1.5243	17.86	0.9334	0.4318	0.7973	1.7044
42	1.4945	17.18	0.9210	0.4605	0.7801	1.6684
43	1.4663	16.52	0.9084	0.4909	0.7627	1.6343
44	1.4396	15.86	0.8955	0.5232	0.7448	1.6018
45	1.4142	15.22	0.8823	0.5576	0.7267	1.5710
MA	Fratio	Amin	L1=L3	L2	C2	W2
		C 03 20		DUAL		

Adapted from A.I.Zverev " Handbook of Filter Synthesis " John Wiley & Sons NY 1967

Since LC elliptic filters are much used at radio frequencies and have an input impedance that is reactive, the voltage standing wave ratio (VSWR) of the filter is of great importance. The reflection coefficient referred to in the previous paragraph has the same meaning as reflection coefficient when dealing with aerials: it is a measure of the power (expressed as %) that is reflected back to the driving source and is simply given by (VSWR−1)/(VSWR+1). At audio frequencies one is not interested in the reflection coefficient, but the magnitude of the passband ripple is of concern. The relationship between reflection coefficient, VSWR, and passband ripple is shown in Figure 4.9. As indicated on the Figure, for a reflection coefficient of 10%, the VSWR is 1.22 and the passband ripple is only 0.044 dB.

The modular angle was introduced by Cauer as a convenient way of describing the relationship between the cutoff frequency and the stopband frequency, in other words the slope of the response in the transition region. For LP filters, it is simply



MA	Fratio	Amin	C1	C 05 05 C2	L2	NORMAL W2	C3	C4	L4	W4	C5
16	3.6280	77.27	0.7499	0.0209	1.2866	6.0936	1.5431	0.0559	1.2321	3.8076	0.7165
17	3.4203	74.60	0.7478	0.0236	1.2836	5.7353	1.5374	0.0635	1.2221	3.5888	0.7101
18	3.2361	72.08	0.7455	0.0266	1.2803	5.4168	1.5313	0.0716	1.2115	3.3946	0.7032
19	3.0716	69.69	0.7431	0.0297	1.2768	5.1318	1.5249	0.0802	1.2002	3.2212	0.6959
20	2.9238	67.41	0.7406	0.0330	1.2732	4.8753	1.5182	0.0895	1.1884	3.0654	0.6883
21	2.7904	65.25	0.7379	0.0365	1.2694	4.6433	1.5112	0.0994	1.1760	2.9246	0.6802
22	2.6695	63.18	0.7350	0.0402	1.2653	4.4323	1.5038	0.1099	1.1630	2.7970	0.6717
23	2.5593	61.20	0.7321	0.0441	1.2611	4.2397	1.4962	0.1210	1.1494	2.6807	0.6628
24	2.4586	59.29	0.7290	0.0482	1.2567	4.0631	1.4882	0.1329	1.1353	2.5743	0.6534
25	2.3662	57.46	0.7257	0.0524	1.2520	3.9007	1.4800	0.1454	1.1205	2.4767	0.6437
26	2.2812	55.70	0.7223	0.0569	1.2472	3.7507	1.4715	0.1588	1.1052	2.3868	0.6335
27	2.2027	54.00	0.7187	0.0617	1.2421	3.6119	1.4627	0.1729	1.0893	2.3038	0.6229
28	2.1301	52.35	0.7150	0.0666	1.2369	3.4829	1.4537	0.1879	1.0729	2.2270	0.6118
29	2.0627	50.76	0.7112	0.0718	1.2314	3.3629	1.4444	0.2038	1.0559	2.1556	0.6003
30	2.0000	49.22	0.7072	0.0772	1.2257	3.2508	1.4348	0.2206	1.0383	2.0892	0.5884
31	1.9416	47.72	0.7030	0.0828	1.2198	3.1460	1.4250	0.2384	1.0201	2.0274	0.5760
32	1.8871	46.27	0.6987	0.0887	1.2136	3.0476	1.4150	0.2574	1.0015	1.9695	0.5631
33	1.8361	44.85	0.6942	0.0948	1.2073	2.9553	1.4048	0.2774	0.9822	1.9154	0.5498
34	1.7883	43.47	0.6896	0.1012	1.2007	2.8683	1.3943	0.2988	0.9625	1.8646	0.5360
35	1.7434	42.13	0.6847	0.1078	1.1938	2.7864	1.3837	0.3214	0.9422	1.8170	0.5217
36	1.7013	40.81	0.6798	0.1148	1.1867	2.7089	1.3729	0.3455	0.9214	1.7722	0.5070
37	1.6616	39.53	0.6746	0.1220	1.1794	2.6356	1.3619	0.3712	0.9001	1.7299	0.4917
38	1.6243	38.28	0.6693	0.1295	1.1717	2.5662	1.3508	0.3985	0.8782	1.6901	0.4759
39	1.5890	37.05	0.6637	0.1374	1.1638	2.5003	1.3396	0.4278	0.8559	1.6525	0.4595
40	1.5557	35.85	0.6580	0.1456	1.1556	2.4377	1.3282	0.4590	0.8331	1.6170	0.4426
41	1.5243	34.67	0.6521	0.1541	1.1472	2.3781	1.3168	0.4924	0.8099	1.5833	0.4252
42	1.4945	33.52	0.6460	0.1630	1.1384	2.3213	1.3053	0.5283	0.7862	1.5515	0.4072
43	1.4663	32.38	0.6397	0.1722	1.1292	2.2672	1.2937	0.5669	0.7620	1.5213	0.3885
44	1.4396	31.27	0.6332	0.1819	1.1198	2.2154	1.2822	0.6085	0.7375	1.4926	0.3693
45	1.4142	30.17	0.6265	0.1920	1.1099	2.1660	1.2706	0.6535	0.7125	1.4654	0.3494
46	1.3902	29.09	0.6195	0.2025	1.0997	2.1187	1.2591	0.7022	0.6871	1.4396	0.3288
47	1.3673	28.03	0.6124	0.2135	1.0891	2.0733	1.2478	0.7550	0.6614	1.4150	0.3075
48	1.3456	26.99	0.6050	0.2251	1.0780	2.0299	1.2365	0.8126	0.6354	1.3916	0.2855
49	1.3250	25.95	0.5973	0.2372	1.0665	1.9881	1.2254	0.8756	0.6090	1.3693	0.2628
50	1.3054	24.94	0.5894	0.2498	1.0545	1.9480	1.2145	0.9446	0.5824	1.3481	0.2392
51	1.2868	23.93	0.5813	0.2632	1.0420	1.9095	1.2039	1.0206	0.5556	1.3279	0.2147
52	1.2690	22.94	0.5729	0.2772	1.0289	1.8724	1.1937	1.1047	0.5285	1.3087	0.1894
53	1.2521	21.96	0.5642	0.2920	1.0152	1.8366	1.1838	1.1980	0.5013	1.2903	0.1631
54	1.2361	20.99	0.5552	0.3076	1.0008	1.8021	1.1744	1.3020	0.4740	1.2728	0.1357
55	1.2208	20.04	0.5460	0.3242	0.9858	1.7689	1.1656	1.4187	0.4467	1.2561	0.1073
56	1.2062	19.09	0.5364	0.3417	0.9700	1.7368	1.1575	1.5502	0.4194	1.2402	0.0777
57	1.1924	18.15	0.5264	0.3605	0.9533	1.7057	1.1501	1.6993	0.3921	1.2250	0.0468
58	1.1792	17.23	0.5163	0.3805	0.9358	1.6757	1.1437	1.8693	0.3651	1.2104	0.0145

MA	Fratio	Amin	L1	C 05 05 L2	C2	DUAL W2	L3	L4	C4	W4	L5

Adapted from A.I.Zverev " Handbook of Filter Synthesis " John Wiley & Sons NY 1967

Figure 4.9. The relationship between reflection coefficient, VSWR, and passband ripple.

the angle whose sine is the ratio of the cutoff frequency to the stopband frequency. As the modular angle gets closer to 90 degrees, the filter response in the transition region gets steeper and indeed gets closer to 90 degrees (i.e: closer to being a 'brick wall' filter).

Since elliptic filters are equiripple, they behave the same way as Chebychev filters in the passband. This means that only odd order filters can be designed for equal source and load resistors. Elliptic filters are so important that modifications have been made to even order filters to permit them to be used between equal source and load resistors. These modified filters are given a designation such as C 05 20c 50, for example, the letter 'c' being added after the reflection coefficient. For these filters, the modular angle is not exactly equal to the sine of the ratio of the cutoff to the stopband frequency and allowance must be made for this in the calculations.

In this issue of AEM, and in the next two, we will be reprinting selected portions of the elliptic filter tables. For those who would like to see a more complete copy of the tables I would recommend that you borrow the book "Electronic Filter Design Handbook" by Arthur B. Williams published by McGraw-Hill in 1981. It is available from many libraries. Indeed, if you are going to buy any book on filters, this is the one that I would recommend. It only contains tables for reflection coefficients of 5% and 20%, but for most purposes this is quite sufficient. Zverev's book has tables from 1% to 50% if you wish to see a really complete set, but it is altogether too expensive to buy.

				C 05 20		NORMAL					
MA	Fratio	Amin	C1	C2	L2	W2	C3	C4	L4	W4	C5
16	3.6280	89.48	1.2849	0.0203	1.3247	6.0936	2.0729	0.0537	1.2841	3.8076	1.2526
17	3.4203	86.81	1.2826	0.0230	1.3220	5.7353	2.0657	0.0608	1.2763	3.5888	1.2463
18	3.2361	84.29	1.2803	0.0258	1.3191	5.4168	2.0582	0.0684	1.2679	3.3946	1.2395
19	3.0716	81.89	1.2778	0.0289	1.3161	5.1318	2.0502	0.0766	1.2591	3.2212	1.2324
20	2.9238	79.62	1.2751	0.0321	1.3129	4.8753	2.0418	0.0852	1.2498	3.0654	1.2249
21	2.7904	77.46	1.2724	0.0354	1.3095	4.6433	2.0330	0.0943	1.2401	2.9246	1.2170
22	2.6695	75.39	1.2694	0.0390	1.3059	4.4323	2.0238	0.1039	1.2299	2.7970	1.2088
23	2.5593	73.40	1.2664	0.0427	1.3022	4.2397	2.0142	0.1141	1.2192	2.6807	1.2001
24	2.4586	71.50	1.2631	0.0467	1.2982	4.0631	2.0041	0.1249	1.2081	2.5743	1.1911
25	2.3662	69.67	1.2598	0.0508	1.2941	3.9007	1.9937	0.1363	1.1965	2.4767	1.1816
26	2.2812	67.91	1.2562	0.0551	1.2899	3.7507	1.9828	0.1482	1.1845	2.3868	1.1718
27	2.2027	66.21	1.2526	0.0596	1.2854	3.6119	1.9716	0.1608	1.1720	2.3038	1.1616
28	2.1301	64.56	1.2488	0.0644	1.2808	3.4829	1.9600	0.1740	1.1591	2.2270	1.1511
29	2.0627	62.97	1.2448	0.0693	1.2759	3.3629	1.9479	0.1878	1.1458	2.1556	1.1401
30	2.0000	61.43	1.2407	0.0745	1.2709	3.2508	1.9355	0.2024	1.1320	2.0892	1.1287
31	1.9416	59.93	1.2364	0.0798	1.2657	3.1460	1.9227	0.2177	1.1177	2.0274	1.1170
32	1.8871	58.47	1.2319	0.0854	1.2603	3.0476	1.9095	0.2337	1.1031	1.9695	1.1049
33	1.8361	57.06	1.2273	0.0913	1.2547	2.9553	1.8960	0.2505	1.0880	1.9154	1.0924
34	1.7883	55.68	1.2225	0.0973	1.2489	2.8683	1.8820	0.2682	1.0724	1.8646	1.0794
35	1.7434	54.33	1.2176	0.1036	1.2429	2.7864	1.8677	0.2867	1.0565	1.8170	1.0661
36	1.7013	53.02	1.2124	0.1102	1.2367	2.7089	1.8531	0.3061	1.0401	1.7722	1.0524
37	1.6616	51.74	1.2071	0.1170	1.2303	2.6356	1.8381	0.3265	1.0233	1.7299	1.0384
38	1.6243	50.49	1.2017	0.1241	1.2236	2.5662	1.8227	0.3480	1.0061	1.6901	1.0239
39	1.5890	49.26	1.1960	0.1315	1.2168	2.5003	1.8070	0.3704	0.9885	1.6525	1.0090
40	1.5557	48.06	1.1902	0.1391	1.2097	2.4377	1.7909	0.3941	0.9705	1.6170	0.9937
41	1.5243	46.88	1.1841	0.1471	1.2024	2.3781	1.7746	0.4189	0.9521	1.5833	0.9780
42	1.4945	45.72	1.1779	0.1553	1.1949	2.3213	1.7578	0.4451	0.9334	1.5515	0.9619
43	1.4663	44.59	1.1714	0.1639	1.1871	2.2672	1.7408	0.4727	0.9142	1.5213	0.9454
44	1.4396	43.47	1.1648	0.1728	1.1790	2.2154	1.7235	0.5017	0.8946	1.4926	0.9284
45	1.4142	42.38	1.1579	0.1821	1.1708	2.1660	1.7058	0.5324	0.8747	1.4654	0.9111
46	1.3902	41.30	1.1509	0.1917	1.1622	2.1187	1.6879	0.5648	0.8544	1.4396	0.8933
47	1.3673	40.23	1.1436	0.2017	1.1534	2.0733	1.6697	0.5990	0.8338	1.4150	0.8750
48	1.3456	39.19	1.1361	0.2120	1.1443	2.0299	1.6512	0.6353	0.8128	1.3916	0.8564
49	1.3250	38.15	1.1283	0.2229	1.1348	1.9881	1.6324	0.6739	0.7914	1.3693	0.8373
50	1.3054	37.13	1.1203	0.2342	1.1251	1.9480	1.6134	0.7148	0.7697	1.3481	0.8177
51	1.2868	36.12	1.1121	0.2460	1.1151	1.9095	1.5941	0.7584	0.7477	1.3279	0.7977
52	1.2690	35.13	1.1035	0.2582	1.1047	1.8724	1.5747	0.8049	0.7254	1.3087	0.7772
53	1.2521	34.14	1.0948	0.2710	1.0940	1.8366	1.5549	0.8547	0.7028	1.2903	0.7562
54	1.2361	33.17	1.0857	0.2843	1.0829	1.8021	1.5350	0.9079	0.6799	1.2728	0.7347
55	1.2208	32.20	1.0763	0.2983	1.0715	1.7689	1.5150	0.9652	0.6567	1.2561	0.7127
56	1.2062	31.25	1.0667	0.3129	1.0596	1.7368	1.4947	1.0268	0.6332	1.2402	0.6902
57	1.1924	30.30	1.0567	0.3282	1.0473	1.7057	1.4743	1.0934	0.6095	1.2250	0.6671
58	1.1792	29.36	1.0464	0.3442	1.0346	1.6757	1.4538	1.1656	0.5855	1.2104	0.6434
59	1.1666	28.42	1.0357	0.3611	1.0213	1.6467	1.4332	1.2441	0.5614	1.1966	0.6192
60	1.1547	27.49	1.0247	0.3789	1.0076	1.6185	1.4125	1.3297	0.5370	1.1834	0.5944
MA	Fratio	Amin	L1	L2	C2	W2	L3	L4	C4	W4	L5
				C 05 20		DUAL					

Adapted from A.I.Zverev " Handbook of Filter Synthesis " John Wiley & Sons NY 1967

Elliptic LC filter design

If you tell the program of Figure 4.10 the details of an LC elliptic LP, HP, BP, or BR filter that you wish to construct, it will tell you which normalized LP filter to look up in the tables. The program will ask you to enter the values of the various normalized component values and normalized frequencies that you have looked up. The program then converts these values to appropriate ones for the type of filter that you requested, scales them to allow for the frequency and source resistance that you have chosen, and then converts them to the appropriate units for display. Since the only values of the reflection coefficient available in the tables are 5% and 20%, there isn't much choice for the allowable ripple, but since the maximum corresponds to about 0.18 dB, this is not really a strain.

When you request the program to design an HP filter, it asks for the normalized values for the dual of the LP filter. One of the many advantages of using normalized tables is that the numerical values of the Ls in a dual are identical with those of the corresponding Cs in the normal circuit and vice versa. So you will find that the headings at the top of a column for a component of the normal filter correspond to those of the equivalent component of the dual given at the bottom of the same column. The reason for using the dual in this instance is to reduce the number of inductors. As we have seen in Figure 4.6, the normal LP circuit has few inductors but lots of capacitors. If the normal circuit was transformed to the HP circuit, all these capacitors would get converted into inductors. The dual, however, has lots of inductors and few capacitors, so this is the obvious place to start for transformation into the HP filter.

Figure 4.10. GWBASIC programme to calculate the components for LC elliptic LP, HP, BP, or BR filters.
The only places where speed is essential are in the calculation of the filter order and in the evaluation of the elliptic integral, so only these parts of the programme have been optimized for speed. In the rest of the program, headings have been included to identify the major blocks.

```
10 PRINT "                    Design of"
20 PRINT "       LC Elliptic LP, HP, BP, & BR filters"
30 PRINT "            using published filter tables."
40 PRINT "     Copyright Aguila Holdings Pty Ltd 1987":PRINT
50 DIM K(25),L(11),C(11),LA(11),LB(11),CA(11),CB(11)
60 REM _____ SET UP STRINGS FOR DISPLAY _____
70 PI=3.141592654#:LGE=.434294481#
80 A1$="L(":A2$="C(":A3$=")="
90 A4$="Tune L(":A7$=") to ":A9$=")C(":A10$="Ca(":A11$="Cb(":A12$="La("
100 A13$="Lb(":A14$="Tune La(":A15$="Tune Lb(":A16$=")Ca(":A17$=")Cb("
110 REM _____ READ IN & CHECK FILTER DATA _____
120 PRINT "What type of filter would you like to design ?"
130 PRINT "1. Low pass "
140 PRINT "2. High pass "
150 PRINT "3. Band pass "
160 PRINT "4. Band reject "
170 PRINT "5. None, Quit."
180 INPUT "Please enter the appropriate integer.",X
190 IF X=5 THEN 1400
200 IF(X<1 OR X>5)THEN 120
210 INPUT "What is the value [ Ohms ] of the source (&load) resistance ?",R:IF R
<=0 THEN 210
220 IF(X=1 OR X=2)THEN INPUT "What is the cutoff frequency [ Hz ] ?",FC:IF FC<=0
 THEN 220 ELSE 260
230 INPUT "What is the centre frequency [ Hz ] ?",FC:IF FC<=0 THEN 230
240 INPUT "What is the bandwidth [ Hz ] ?",BW:IF BW<=0 THEN 240
250 FL=(-BW+SQR(BW*BW+4*FC*FC))/2:FU=FL+BW:IF FL<=0 THEN PRINT"That bandwidth is
 too wide for the centre frequency.":GOTO 230
260 INPUT "At what frequency [ Hz ] in the stopband is the attenuation known ?",
F1:IF F1<=0 THEN 260
270 IF((X=1 AND F1<=FC) OR (X=2 AND F1>=FC) OR (X=3 AND (F1>=FL AND F1<=FU)) OR
(X=4 AND (F1<=FL OR F1>=FU)))THEN 280 ELSE 290
280 PRINT"That frequency is not in the stopband.": GOTO 260
290 IF (X=4 AND F1=FC)THEN PRINT"Sorry I can't use the centre frequency, please
choose another frequency.":GOTO 260
300 INPUT "What is the attenuation [ dB ] at that frequency ?",ASTOP:IF ASTOP<=3
 THEN PRINT"There must be more than 3 dB attenuation in the stopband.":GOTO 300
310 INPUT "What ripple [ less than 0.175 dB ] would you like in the passband [ d
B ] ?",A1: IF A1<0 THEN 310
320 REM _____ SET UP FREQUENCY RATIO _____
330 FRATIO=F1/FC:IF X=2 THEN FRATIO=FC/F1
340 IF X=3 THEN FRATIO=ABS(F1-FC*FC/F1)/BW
350 IF X=4 THEN FRATIO=BW/ABS(F1-FC*FC/F1)
360 REM _____ CALCULATE FILTER ORDER _____
370 EP1=10^(.1*ASTOP)-1 : EP2=10^(.1*A1)-1
380 K=SQR(1-1/FRATIO/FRATIO) : GOSUB 450 : K3=K4
390 K=1/FRATIO : GOSUB 450 : K0=K4
400 L=SQR(EP1/EP2) : K=1/L : GOSUB 450 : K1=K4
410 IF L<4000 THEN K=SQR(1-1/L/L) ELSE SW=1
420 GOSUB 450 : K2=K4 : NELLIP =INT(K2/K1*K0/K3)+1:IF NELLIP=4 THEN NELLIP=5
430 GOTO 490
440 REM _____ EVALUATE ELLIPTIC INTEGRAL _____
450 K(0)=K : P=1 : I=1 : IF SW=1 THEN K(1)=(1-1/L)/(1+1/L) : I=2
460 SQK=SQR(1-K(I-1)*K(I-1)) : K(I)=(1-SQK)/(1+SQK)
470 IF K(I)>.0000001 THEN I=I+1 : GOTO 460
480 FOR J=1 TO I : P=P*(1+K(J)) : NEXT J : K4=P*PI/2 : RETURN
490 IF NELLIP>11 THEN PRINT "Tables are only available up to Order 11.":GOTO 120
500 REM _____ CALCULATE REFLECTION COEFFT & MODULAR ANGLE _____
510 Z=1/FRATIO : A=INT(180*ATN(Z/SQR(1-Z*Z))/PI)
520 RC=INT(100*SQR(1-10^(-A1/10)))
530 IF RC>20 THEN PRINT "The reflection coefficient is greater than 20, so there
 are no suitable tables.":GOTO 120
540 IF RC<=5 AND NELLIP<6 THEN B$=" 05 " ELSE B$=" 20 "
550 REM _____ ALLOW FOR MODIFIED EVEN ORDER FILTERS _____
560 IF NELLIP>=6 AND NELLIP MOD 2=0 THEN B$=" 20c ":A=A+2
570 IF NELLIP<>6 THEN 600
580 IF A>38 AND A<=58 THEN A=A+1 ELSE IF A>58 AND A<=75 THEN A=A+2
590 REM _____ REQUEST COMPONENT DATA _____
600 IF NELLIP<10 THEN A$="Would you please look up the values for filter C 0":PR
INT USING "\                                        \#\   \##":A$,NELLIP
,B$,A
610 IF NELLIP>=10 THEN A$="Would you please look up the values for filter C ":PR
INT USING "\                                        \##\   \##":A$,NELLIP
,B$,A
620 IF X=2 THEN PRINT:PRINT "Please make sure you look up the values for the DUA
L filter.":PRINT "The headings for this are at the bottom of the table.":PRINT
625 REM _____
630 ON X GOTO 640,720,640,640
640 FOR I=1 TO NELLIP
650 IF NELLIP MOD 2<>0 THEN 670
660 IF I=NELLIP THEN PRINT "What is the value of L"I":INPUT L(I):GOTO 800
670 PRINT "What is the value of C"I":INPUT C(I)
680 IF I MOD 2<>0 THEN 710
690 PRINT "What is the value of L"I" : INPUT L(I)
700 PRINT "What is the value of Omega"I":INPUT W(I)
710 NEXT I:GOTO 800
715 REM _____
720 FOR I=1 TO NELLIP
730 IF NELLIP MOD 2<>0 THEN 750
740 IF I=NELLIP THEN PRINT "What is the value of C"I":INPUT C(I):GOTO 800
750 PRINT "What is the value of L"I":INPUT L(I)
760 IF I MOD 2<>0 THEN 790
770 PRINT "What is the value of C"I":INPUT C(I)
780 PRINT "What is the value of Omega"I":INPUT W(I)
790 NEXT I
795 REM _____
800 CFACTOR=1/2/PI/FC/R:LFACTOR=R/2/PI/FC 'Denormalizing factors for L & C
810 ON X GOTO 830,870,920,1040
820 REM _____ CALCULATE VALUES FOR LP FILTERS _____
830 FOR I=1 TO NELLIP:C(I)=C(I)*CFACTOR
840 IF I MOD 2=0 THEN L(I)=L(I)*LFACTOR:W(I)=W(I)*FC
850 NEXT I:GOTO 1140
860 REM _____ CALCULATE VALUES FOR HP FILTERS _____
870 FOR I=1 TO NELLIP:IF NELLIP MOD 2=0 AND I=NELLIP THEN L(I)=LFACTOR/C(I):GOTO
 1150
880 CC=C(I):C(I)=CFACTOR/L(I)
890 IF I MOD 2=0 THEN L(I)=LFACTOR/CC:W(I)=FC/W(I)
900 NEXT I:GOTO 1140
910 REM _____ CALCULATE VALUES FOR BP FILTERS _____
920 QBP=FC/BW:FOR I=1 TO NELLIP STEP 2
930 L(I)=LFACTOR/C(I)/QBP
940 IF NELLIP MOD 2=0 AND I=NELLIP THEN 960
950 C(I)=C(I)*QBP*CFACTOR
960 NEXT I
970 FOR I=2 TO NELLIP-1 STEP 2
980 L=L(I)*QBP:C=C(I)*QBP:B=1+.5/L/C+SQR(.25/L/L/C/C+1/L/C)
990 LA(I)=1/C/(B+1):LB(I)=B*LA(I):CA(I)=1/LB(I):CB(I)=1/LA(I):WA(I)=SQR(B)*FC:WB
(I)=FC/SQR(B)
1000 LA(I)=LFACTOR*LA(I):LB(I)=LFACTOR*LB(I):CA(I)=CFACTOR*CA(I):CB(I)=CFACTOR*C
B(I):NEXT I
1010 IF NELLIP MOD 2=0 THEN C(NELLIP)=CFACTOR/QBP/L(NELLIP):L(NELLIP)=LFACTOR*QB
P*L(NELLIP)
1020 GOTO 1140
1030 REM _____ CALCULATE VALUES FOR BR FILTERS _____
1040 QBR=FC/BW:FOR I=1 TO NELLIP STEP 2
1050 L(I)=LFACTOR*QBR/C(I)
1060 IF NELLIP MOD 2=0 AND I=NELLIP THEN 1080
1070 C(I)=CFACTOR*C(I)/QBR
1080 NEXT I
1090 FOR I=2 TO NELLIP-1 STEP 2
1100 L=QBR/C(I):C=QBR/L(I):B=1+.5/L/C+SQR(.25/L/L/C/C+1/L/C)
1110 LA(I)=1/C/(B+1):LB(I)=B*LA(I):CA(I)=1/LB(I):CB(I)=1/LA(I):WA(I)=FC*SQR(B):W
B(I)=FC/SQR(B)
1120 LA(I)=LFACTOR*LA(I):LB(I)=LFACTOR*LB(I):CA(I)=CFACTOR*CA(I):CB(I)=CFACTOR*C
B(I):NEXT I
1130 IF NELLIP MOD 2=0 THEN C(NELLIP)=CFACTOR*QBR/L(NELLIP):L(NELLIP)=LFACTOR*L(
NELLIP)/QBR
1140 ON X GOTO 1160,1160,1240,1240
1150 REM _____ DISPLAY RESULTS FOR LP & HP FILTERS_____
1160 FOR I=1 TO NELLIP
1170 IF NELLIP MOD 2=0 AND I=NELLIP THEN LL=L(I):GOSUB 1460:PRINT USING "\\##\\#
###.###\ \";A1$,I,A3$,LL,A8$:GOTO 1400
1180 CC=C(I):GOSUB 1420:PRINT USING "\\##\\####.###\ \";A2$,I,A3$,CC,A8$
1190 IF I MOD 2<>0 THEN 1220
1200 LL=L(I):GOSUB 1460:PRINT USING "\\##\\####.###\ \";A1$,I,A3$,LL,A8$
1210 W=W(I):GOSUB 1510:PRINT USING "\      \##\ \##\   \###.###\  \";A4$,I,A9$,I,
A7$,W,A6$
1220 NEXT I:GOTO 1400
1230 REM _____ DISPLAY RESULTS FOR BP & BR FILTERS_____
1240 FOR I=1 TO NELLIP
1250 IF I MOD 2=0 THEN 1290
1260 CC=C(I):GOSUB 1420:PRINT USING "\\##\\####.###\ \";A2$,I,A3$,CC,A8$
1270 LL=L(I):GOSUB 1460:PRINT USING "\\##\\####.###\ \";A1$,I,A3$,LL,A8$
1280 W=FC:GOSUB 1510:PRINT USING "\      \##\ \##\   \###.###\  \";A4$,I,A9$,I,A7
$,W,A6$:GOTO 1390
1290 IF NELLIP MOD 2=0 AND I=NELLIP THEN 1360
1300 CC=CA(I):GOSUB 1420:PRINT USING "\ \##\\####.###\ \";A10$,I,A3$,CC,A8$
1310 LL=LA(I):GOSUB 1460:PRINT USING "\ \##\\####.###\ \";A12$,I,A3$,LL,A8$
1320 W=WA(I):GOSUB 1510:PRINT USING "\      \##\ \##\   \###.###\  \";A14$,I,A1
6$,I,A7$,W,A6$
1330 CC=CB(I):GOSUB 1420:PRINT USING "\ \##\\####.###\ \";A11$,I,A3$,CC,A8$
1340 LL=LB(I):GOSUB 1460:PRINT USING "\ \##\\####.###\ \";A13$,I,A3$,LL,A8$
1350 W=WB(I):GOSUB 1510:PRINT USING "\      \##\ \##\   \###.###\  \";A15$,I,A1
7$,I,A7$,W,A6$:GOTO 1390
1360 LL=L(I):GOSUB 1460:PRINT USING "\\##\\###.###\ \";A1$,I,A3$,LL,A8$
1370 CC=C(I):GOSUB 1420:PRINT USING "\\##\\####.###\ \";A2$,I,A3$,CC,A8$
1380 W=FC:GOSUB 1510:PRINT USING "\      \##\ \##\   \###.###\  \";A4$,I,A9$,I,A7
$,W,A6$
1390 NEXT I
1400 PRINT "End of programme.":END
1410 REM _____ SUBROUTINES FOR CONVENIENT UNITS _____
1420 IF CC>=.000001 THEN CC=CC*1000000!:A8$=" uF":GOTO 1450
1430 IF CC>=1E-09 THEN CC=CC*1E+09:A8$=" nF":GOTO 1450
1440 CC=CC*1E+12:A8$=" pF"
1450 RETURN
1460 IF LL>=1 THEN A8$=" H ":GOTO 1500
1470 IF LL>=.001 THEN LL=LL*1000!:A8$=" mH":GOTO 1500
1480 IF LL>=.000001 THEN LL=LL*1000000!:A8$=" uH":GOTO 1500
1490 LL=LL*1E+09:A8$=" nH":GOTO 1500
1500 RETURN
1510 IF W>=1000000! THEN W=W/1000000!:A6$=" MHz":GOTO 1540
1520 IF W>=1000! THEN W=W/1000!:A6$=" kHz":GOTO 1540
1530 A6$=" Hz"
1540 RETURN
```

Because of the difference between odd and even elliptic filters, there are lots of statements that start IF NELLIP MOD 20 (to see if the order is even) followed by a branch to a different part of the program. This is particularly the case when calculating the values for the components and in the display sections.

Because there are no tables for modified 4th order filters, if your filter requirements would have necessitated the use of a 4th order filter, the program will automatically select the nearest 5th order filter for you. It is important to realize that this is just a computer program and that it is you who are designing the filter. If the program asks you to look up filter C 05 20 47, by all means do so, but check the value of Fratio and Amin to see if a nearby filter might be better suited to your purpose. For the C 05 20 47, these values are 1.3673 and 40.23 respectively. This means that this filter has an attenuation of 40.23 dB when the ratio of the stopband frequency to the cutoff frequency is 1.3673.

You may decide that you would prefer 46.88 dB at a frequency ratio of 1.523, in which case you would select the filter C 05 20 41 and feed the values from this filter into the program. The choice of which filter you want is yours, the program simply does the necessary arithmetic for you. When you are designing a BP or BR filter, things are a bit different. The program has to decide which normalized LP filter will transform into the filter that you want. This is rather complicated, so in this case it is best to stick with the filter that it chooses.

Computer problems

Before we go any further we had better discuss a slight problem. The evaluation of the complete elliptic integral is no easy task for a desktop computer. The standard program to do this is given in Figure 4.11 and involves the ATAN, SIN, COS, TAN, SQR, and LOG functions. Because it uses so many functions, it is slow and can crash because of accumulated roundoff errors caused by the limited accuracy of the algorithms used in the GWBASIC software to generate these functions. To speed things up, the integral is evaluated in Figure 4.10 using an algorithm developed by the author. This only uses the SQR function, but without help, even this can get into difficulties. If you choose a passband ripple that is below about 0.15 dB, the variable SQK on line 460 becomes close to zero and the SQR function in GWBASIC will jump to the answer zero. This leaves lines 460-470 in a never-ending loop which will overflow the dimensions of the array K(), set on line 50.

To avoid this, the program of Figure 4.10 includes the switch SW on lines 410 and 450. When the input variable K gets close to 1.0, this switches the program to use a numerical approximation to the square root of a number near zero, and the computer's SQR function is not used. If you are lucky enough to have a machine that uses 64-bit or 80-bit algorithms, tests have shown that you can take these safety measures out and simply use:

410 K = SQR(1-1/L/L) and
450 K(0) = K : P = 1 : I = 1 in Figure 4.10.

If you aren't that lucky, and you like to experiment, you can try the standard program of Figure 4.11 to see how it goes in your particular computer, but don't be surprised if the computer starts putting out complaining messages, or suddenly reboots, or goes away and sulks. It won't do it any harm (I hope !) but it does show the limitations of the 32-bit mathematical software used in most 16-bit machines. Incidentally, making all the variables double precision does not help since the trouble lies in the SQR algorithm which is inherently "single" precision and therefore limited to 6 or 7 decimal places. With the safety measures in place, the program as shown in Figure 4.10 works satisfactorily with 16 bit machines.

Constructing Elliptic LC filters

The program of Figure 4.10, as well as displaying a list of the component values, displays the required tuning frequencies for each of the tuned circuits. When building these filters, remember to put in links so that each tuned circuit can be isolated and tuned to its correct frequency. This can add up to a lot of links, since the series tuned circuits have to be isolated at each end because one end has to be grounded for tuning to take place.

Figure 4.11. Standard GWBASIC program to evaluate the complete elliptic integral of the first kind.

The input variable is K and the integral is K4. This block of programme can be used in place of lines 450-480 in Figure 4.10, for example, if you would like to experiment. Be particularly careful when typing this program otherwise if it crashes you won't know why.

```
450 K(0)=ATN(K/SQR(1-K*K)) : KK(0)=PI/2 : P=1 : I=0
455 X=2/(1+SIN(K(0)))-1 : Y=SIN(K(I))*SIN(KK(I))
460 K(I+1)=ATN(SQR(1-X*X)/X)
465 KK(I+1)=.5*(KK(I)+ATN(Y/SQR(1-Y*Y)))
470 E=1-K(I+1)*2/PI : I=I+1 : IF E>.0000001 THEN 455
475 FOR J=1 TO I : P=P*(1+COS(K(J))) : NEXT J
480 X=PI/4+KK(I)/2 : K4=LOG(TAN(X))*P : RETURN
```

For all elliptic filters it is essential to include a single turn tuning winding if you are using potcores, otherwise tuning becomes a real problem. Also it is imperative that there be no coupling between the various inductors, so your layout has to be carefully designed. For RF, a ground plane is essential, and double-sided printed circuit board with alternate inductors on opposite sides of the board is a good idea. It may be necessary to use small pieces of double sided PCB, soldered at right angles to the main board, as shields between inductors. It is also essential to keep the length of the links to a minimum, certainly no longer than 4 mm.

As an example, let us do a complete design of a filter suitable for use between the transmitter and aerial of a low powered amateur station operating in the frequency range 28.0 to 29.7 MHz. To remove any unwanted interference with nearby transmissions, it is decided to have a filter that will attenuate any output at 27 MHz by at least 60 dB.

Since a bandpass filter is going to be used, frequencies above 30.8 MHz will also be attenuated by at least 60 dB. Using the program of Figure 4.10 and with filter data of Rsource = 52

C 06 20c NORMAL

NA	Fratio	Amin	C1	C2	L2	W2	C3	C4	L4	W4	C5	L6
31	2.0608	77.10	1.0770	0.0822	1.4180	2.9287	1.6600	0.1392	1.5830	2.1298	1.4200	1.1550
32	2.0016	75.30	1.0710	0.0880	1.4100	2.8385	1.6480	0.1492	1.5670	2.0681	1.4130	1.1550
33	1.9463	73.60	1.0650	0.0940	1.4030	2.7538	1.6360	0.1597	1.5500	2.0103	1.4050	1.1550
34	1.8943	72.00	1.0590	0.1003	1.3950	2.6740	1.6240	0.1706	1.5320	1.9561	1.3980	1.1540
35	1.8455	70.40	1.0530	0.1068	1.3860	2.5990	1.6110	0.1820	1.5140	1.9051	1.3900	1.1540
36	1.7996	68.80	1.0470	0.1135	1.3780	2.5281	1.5980	0.1939	1.4960	1.8571	1.3820	1.1540
37	1.7564	67.30	1.0400	0.1206	1.3690	2.4610	1.5850	0.2063	1.4770	1.8119	1.3740	1.1530
38	1.7156	65.80	1.0330	0.1279	1.3600	2.3975	1.5710	0.2192	1.4570	1.7692	1.3650	1.1530
39	1.6771	64.30	1.0260	0.1355	1.3510	2.3373	1.5570	0.2328	1.4370	1.7289	1.3560	1.1520
40	1.6406	62.80	1.0190	0.1434	1.3410	2.2802	1.5430	0.2469	1.4170	1.6907	1.3480	1.1520
41	1.6061	61.40	1.0120	0.1516	1.3320	2.2258	1.5280	0.2617	1.3960	1.6545	1.3380	1.1510
42	1.5735	60.00	1.0040	0.1601	1.3210	2.1741	1.5130	0.2772	1.3740	1.6203	1.3290	1.1510
43	1.5425	58.70	0.9963	0.1689	1.3110	2.1248	1.4980	0.2933	1.3520	1.5877	1.3190	1.1500
44	1.5130	57.30	0.9882	0.1781	1.3000	2.0777	1.4820	0.3103	1.3300	1.5568	1.3090	1.1500
45	1.4851	56.00	0.9798	0.1877	1.2890	2.0328	1.4660	0.3280	1.3070	1.5274	1.2990	1.1490
46	1.4585	54.70	0.9712	0.1976	1.2780	1.9898	1.4500	0.3465	1.2840	1.4995	1.2890	1.1480
47	1.4332	53.40	0.9624	0.2079	1.2660	1.9487	1.4330	0.3659	1.2600	1.4728	1.2780	1.1480
48	1.4092	52.20	0.9533	0.2187	1.2550	1.9093	1.4160	0.3863	1.2350	1.4475	1.2670	1.1470
49	1.3862	50.90	0.9439	0.2298	1.2420	1.8716	1.3990	0.4078	1.2100	1.4233	1.2560	1.1460
50	1.3644	49.70	0.9343	0.2414	1.2300	1.8353	1.3810	0.4304	1.1850	1.4002	1.2450	1.1460
51	1.3436	48.50	0.9244	0.2535	1.2170	1.8005	1.3630	0.4540	1.1590	1.3782	1.2340	1.1450
52	1.3237	47.30	0.9142	0.2661	1.2040	1.7671	1.3450	0.4790	1.1330	1.3572	1.2220	1.1440
53	1.3048	46.10	0.9037	0.2792	1.1900	1.7349	1.3270	0.5054	1.1070	1.3371	1.2100	1.1430
54	1.2867	45.00	0.8929	0.2929	1.1760	1.7039	1.3080	0.5333	1.0800	1.3179	1.1970	1.1420
55	1.2694	43.80	0.8819	0.3072	1.1620	1.6741	1.2890	0.5628	1.0520	1.2995	1.1850	1.1410
56	1.2529	42.70	0.8705	0.3221	1.1470	1.6453	1.2690	0.5941	1.0240	1.2820	1.1720	1.1400
57	1.2372	41.50	0.8587	0.3377	1.1320	1.6175	1.2490	0.6274	0.9957	1.2652	1.1590	1.1390
58	1.2221	40.40	0.8466	0.3541	1.1160	1.5907	1.2290	0.6629	0.9668	1.2491	1.1450	1.1380
59	1.2078	39.30	0.8342	0.3712	1.1000	1.5648	1.2090	0.7008	0.9375	1.2338	1.1310	1.1370
60	1.1941	38.10	0.8214	0.3892	1.0840	1.5398	1.1880	0.7413	0.9077	1.2191	1.1170	1.1360
61	1.1810	37.00	0.8081	0.4081	1.0670	1.5156	1.1670	0.7848	0.8775	1.2050	1.1030	1.1340
62	1.1685	35.90	0.7945	0.4280	1.0490	1.4921	1.1460	0.8317	0.8468	1.1916	1.0880	1.1330
63	1.1566	34.80	0.7804	0.4490	1.0320	1.4694	1.1250	0.8823	0.8157	1.1787	1.0740	1.1310
64	1.1452	33.70	0.7659	0.4712	1.0130	1.4474	1.1030	0.9372	0.7843	1.1664	1.0580	1.1300
65	1.1343	32.60	0.7509	0.4947	0.9940	1.4261	1.0810	0.9970	0.7524	1.1546	1.0430	1.1280
66	1.1240	31.50	0.7354	0.5196	0.9744	1.4053	1.0590	10.6200	0.7201	1.1434	1.0260	1.1260
67	1.1141	30.40	0.7193	0.5462	0.9542	1.3852	1.0370	1.1340	0.6874	1.1326	1.0100	1.1250
68	1.1047	29.30	0.7027	0.5746	0.9332	1.3656	1.0140	1.2130	0.6543	1.1224	0.9932	1.1230
69	1.0958	28.20	0.6854	0.6050	0.9115	1.3466	0.9915	1.3010	0.6208	1.1126	0.9759	1.1200
70	1.0873	27.10	0.6674	0.6377	0.8891	1.3281	0.9686	1.4000	0.5870	1.1032	0.9582	1.1180
71	1.0793	26.00	0.6488	0.6730	0.8657	1.3101	0.9456	1.5110	0.5528	1.0943	0.9399	1.1160
72	1.0717	24.90	0.6293	0.7114	0.8415	1.2925	0.9225	1.6360	0.5184	1.0858	0.9211	1.1130
73	1.0644	23.70	0.6089	0.7533	0.8162	1.2753	0.8994	1.7800	0.4836	1.0777	0.9017	1.1100
74	1.0576	22.60	0.5876	0.7994	0.7898	1.2586	0.8762	1.9470	0.4486	1.0701	0.8816	1.1070
75	1.0512	21.50	0.5652	0.8503	0.7621	1.2422	0.8530	2.1410	0.4134	1.0628	0.8608	1.1040

NA	Fratio	Amin	L1	L2	C2	W2	L3	L4	C4	W4	L5	C6

C 06 20c DOAL

Adapted from R.Saal and E.Ulbrich, "On the Design of Filters by Synthesis" IRE Trans Circuit Theory, Dec 1958

C 07 20 NORMAL

MA	Fratio	Amin	C1	C2	L2	W2	C3	C4	L4	W4	C5	C6	L6	W6	C7
36	1.7013	84.6	1.2860	0.0578	1.3280	3.6093	1.9730	0.2727	1.2160	1.7366	1.8780	0.1932	1.1810	2.0933	1.1650
37	1.6616	82.8	1.2830	0.0614	1.3240	3.5081	1.9580	0.2900	1.1990	1.6957	1.8580	0.2055	1.1690	2.0400	1.1550
38	1.6243	81.0	1.2800	0.0651	1.3210	3.4121	1.9430	0.3079	1.1820	1.6571	1.8380	0.2183	1.1570	1.9896	1.1450
39	1.5890	79.3	1.2770	0.0689	1.3170	3.3209	1.9280	0.3267	1.1650	1.6206	1.8170	0.2317	1.1450	1.9418	1.1350
40	1.5557	77.6	1.2740	0.0729	1.3130	3.2341	1.9120	0.3462	1.1480	1.5862	1.7950	0.2456	1.1320	1.8966	1.1240
41	1.5243	76.0	1.2700	0.0770	1.3080	3.1513	1.8950	0.3666	1.1300	1.5537	1.7730	0.2601	1.1190	1.8537	1.1130
42	1.4945	74.3	1.2670	0.0812	1.3040	3.0724	1.8790	0.3879	1.1120	1.5229	1.7510	0.2753	1.1050	1.8129	1.1020
43	1.4663	72.7	1.2630	0.0857	1.3000	2.9970	1.8620	0.4101	1.0930	1.4937	1.7280	0.2911	1.0910	1.7740	1.0900
44	1.4396	71.2	1.2590	0.0903	1.2950	2.9248	1.8440	0.4332	1.0740	1.4660	1.7050	0.3076	1.0770	1.7371	1.0780
45	1.4142	69.7	1.2550	0.0950	1.2900	2.8557	1.8260	0.4575	1.0550	1.4396	1.6810	0.3248	1.0630	1.7019	1.0660
46	1.3902	68.2	1.2510	0.1000	1.2850	2.7895	1.8080	0.4828	1.0350	1.4147	1.6570	0.3428	1.0480	1.6683	1.0530
47	1.3673	66.7	1.2470	0.1051	1.2800	2.7259	1.7890	0.5093	1.0150	1.3910	1.6330	0.3617	1.0330	1.6362	1.0400
48	1.3456	65.2	1.2430	0.1105	1.2750	2.6648	1.7700	0.5370	0.9944	1.3685	1.6080	0.3814	1.0170	1.6057	1.0270
49	1.3250	63.7	1.2380	0.1160	1.2690	2.6060	1.7510	0.5661	0.9736	1.3470	1.5830	0.4020	1.0010	1.5763	1.0130
50	1.3054	62.3	1.2340	0.1217	1.2640	2.5494	1.7310	0.5965	0.9525	1.3266	1.5570	0.4235	0.9850	1.5482	0.9992
51	1.2868	60.9	1.2290	0.1277	1.2580	2.4948	1.7110	0.6286	0.9310	1.3072	1.5310	0.4462	0.9684	1.5213	0.9848
52	1.2690	59.5	1.2240	0.1339	1.2520	2.4422	1.6900	0.6622	0.9093	1.2887	1.5040	0.4699	0.9514	1.4956	0.9699
53	1.2521	58.1	1.2190	0.1404	1.2460	2.3913	1.6690	0.6977	0.8872	1.2711	1.4770	0.4948	0.9340	1.4709	0.9547
54	1.2361	56.8	1.2130	0.1471	1.2390	2.3422	1.6480	0.7351	0.8648	1.2543	1.4500	0.5211	0.9163	1.4473	0.9391
55	1.2208	55.4	1.2080	0.1541	1.2320	2.2946	1.6260	0.7745	0.8420	1.2383	1.4220	0.5487	0.8981	1.4245	0.9230
56	1.2062	54.1	1.2020	0.1614	1.2250	2.2485	1.6040	0.8163	0.8190	1.2230	1.3940	0.5778	0.8796	1.4027	0.9065
57	1.1924	52.7	1.1960	0.1690	1.2180	2.2039	1.5810	0.8605	0.7957	1.2085	1.3650	0.6085	0.8607	1.3817	0.8896
58	1.1792	51.4	1.1900	0.1770	1.2110	2.1606	1.5580	0.9075	0.7721	1.1946	1.3360	0.6411	0.8414	1.3616	0.8722
59	1.1666	50.1	1.1830	0.1853	1.2030	2.1185	1.5350	0.9576	0.7482	1.1814	1.3070	0.6755	0.8217	1.3422	0.8543
60	1.1547	48.8	1.1770	0.1939	1.1950	2.0776	1.5110	1.0110	0.7240	1.1689	1.2780	0.7121	0.8016	1.3235	0.8360
61	1.1434	47.5	1.1700	0.2030	1.1860	2.0378	1.4870	1.0680	0.6995	1.1569	1.2480	0.7510	0.7811	1.3056	0.8171
62	1.1326	46.2	1.1630	0.2125	1.1770	1.9990	1.4630	1.1290	0.6748	1.1455	1.2180	0.7925	0.7602	1.2883	0.7976
63	1.1223	44.9	1.1550	0.2225	1.1680	1.9612	1.4380	1.1950	0.6498	1.1346	1.1880	0.8369	0.7389	1.2717	0.7776
64	1.1126	43.7	1.1470	0.2331	1.1590	1.9243	1.4120	1.2670	0.6245	1.1243	1.1570	0.8845	0.7171	1.2556	0.7570
65	1.1034	42.4	1.1390	0.2441	1.1490	1.8883	1.3860	1.3440	0.5990	1.1145	1.1260	0.9357	0.6949	1.2402	0.7357
66	1.0946	41.1	1.1300	0.2558	1.1380	1.8530	1.3600	1.4280	0.5732	1.1052	1.0950	0.9909	0.6722	1.2253	0.7138
67	1.0864	39.8	1.1210	0.2682	1.1270	1.8185	1.3330	1.5200	0.5472	1.0963	1.0640	1.0510	0.6490	1.2110	0.6911
68	1.0785	38.5	1.1120	0.2814	1.1160	1.7847	1.3060	1.6220	0.5209	1.0880	1.0330	1.1160	0.6254	1.1972	0.6676
69	1.0711	37.2	1.1020	0.2953	1.1040	1.7515	1.2780	1.7340	0.4945	1.0800	1.0010	1.1870	0.6013	1.1838	0.6433
70	1.0642	35.9	1.0910	0.3102	1.0910	1.7189	1.2500	1.8590	0.4678	1.0725	0.9689	1.2650	0.5767	1.1710	0.6181
71	1.0576	34.6	1.0800	0.3262	1.0770	1.6869	1.2210	1.9980	0.4409	1.0654	0.9371	1.3510	0.5516	1.1586	0.5920
72	1.0515	33.3	1.0680	0.3433	1.0630	1.6553	1.1920	2.1560	0.4138	1.0587	0.9051	1.4460	0.5259	1.1467	0.5647
73	1.0457	32.0	1.0550	0.3618	1.0480	1.6241	1.1620	2.3360	0.3865	1.0524	0.8731	1.5530	0.4997	1.1352	0.5363
74	1.0403	30.7	1.0420	0.3818	1.0320	1.5933	1.1310	2.5430	0.3591	1.0465	0.8412	1.6730	0.4729	1.1241	0.5066
75	1.0353	29.3	1.0280	0.4037	1.0140	1.5628	1.1000	2.7840	0.3315	1.0410	0.8093	1.8100	0.4455	1.1135	0.4754
76	1.0306	27.9	1.0130	0.4278	0.9953	1.5326	1.0690	3.0680	0.3038	1.0358	0.7776	1.9680	0.4175	1.1032	0.4426
77	1.0263	26.5	0.9960	0.4544	0.9749	1.5025	1.0370	3.4080	0.2760	1.0310	0.7460	2.1510	0.3888	1.0933	0.4079
78	1.0223	25.1	0.9782	0.4841	0.9527	1.4725	1.0040	3.8220	0.2483	1.0266	0.7148	2.3680	0.3595	1.0839	0.3710
79	1.0187	23.6	0.9588	0.5177	0.9282	1.4425	0.9699	4.3370	0.2205	1.0225	0.6841	2.6280	0.3295	1.0747	0.3316
80	1.0154	22.1	0.9376	0.5562	0.9011	1.4125	0.9356	4.9940	0.1929	1.0188	0.6540	2.9460	0.2987	1.0660	0.2892

MA	Fratio	Amin	L1	L2	C2	W2	L3	L4	C4	W4	L5	L6	C6	W6	L7

C 07 20 DUAL

Adapted from R.Saal and E.Ulbrich, "On the Design of Filters by Synthe sis ", IRE Trans Circuit Theory, Dec 1958

Ohms, Centre frequency = 28.886 MHz (remember, this is SQRT(28.0x29.7)), Bandwidth = 1.7 MHz, allowable passband ripple = 0.1 dB, the program asks you to look up the values in the normalized filter C 05 20 25. When the values from this filter are fed into the program, the display gives the following values for the filter elements and tuning frequencies:

C(1) = 2.268 nF
L(1) = 13.385 nH
Tune L(1)C(1) to 28.886 MHz
CA(2) = 164.174 pF
LA(2) = 147.045 nH
Tune LA(2)CA(2) to 32.395 MHz
CB(2) = 206.449 pF
LB(2) = 184.940 nH
Tune LB(2)CB(2) to 25.757 MHz
C(3) = 3.548 nF
L(3) = 8.458 nH
Tune L(3)C(3) to 28.886 MHz
CA(4) = 457.364 pF
LA(4) = 57.380 nH
Tune LA(4)CA(4) to 31.068 MHz
CB(4) = 529.063 pF
LB(4) = 66.375 nH
Tune LB(4)CB(4) to 26.857 MHz
C(5) = 2.127 nF
L(5) = 14.270 nH
Tune L(5)C(5) to 28.886 MHz

The first thing to notice is the small values for the inductors of the tuned circuits that do not produce notches. Each of these coils will only be a single turn about 10 mm in diameter, hence the restriction to low power. Note also that, as with our previous bandpass circuits, these particular tuned circuits have to be

C 08 20c NORMAL

MA	Fratio	Amin	C1	C2	L2	W2	C3	C4	L4	W4	C5	C6	L6	W6	C7	L8
46	1.4278	81.6	1.0850	0.1251	1.3700	2.4152	1.5680	0.3673	1.2970	1.4486	1.3780	0.2435	1.5030	1.6528	1.3420	1.2030
47	1.4036	79.9	1.0790	0.1315	1.3630	2.3623	1.5510	0.3871	1.2740	1.4237	1.3580	0.2565	1.4830	1.6214	1.3340	1.2020
48	1.3806	78.2	1.0730	0.1381	1.3550	2.3115	1.5340	0.4078	1.2510	1.4000	1.3380	0.2701	1.4620	1.5913	1.3250	1.2010
49	1.3587	76.5	1.0660	0.1450	1.3470	2.2628	1.5160	0.4295	1.2270	1.3775	1.3170	0.2842	1.4410	1.5626	1.3170	1.2000
50	1.3379	74.9	1.0590	0.1521	1.3390	2.2159	1.4980	0.4521	1.2030	1.3560	1.2960	0.2990	1.4190	1.5351	1.3080	1.2000
51	1.3180	73.3	1.0520	0.1595	1.3300	2.1707	1.4790	0.4759	1.1780	1.3355	1.2750	0.3144	1.3970	1.5089	1.2990	1.1990
52	1.2991	71.7	1.0450	0.1672	1.3220	2.1272	1.4600	0.5008	1.1530	1.3160	1.2530	0.3305	1.3740	1.4836	1.2900	1.1980
53	1.2811	70.1	1.0370	0.1751	1.3130	2.0853	1.4410	0.5269	1.1280	1.2973	1.2310	0.3474	1.3510	1.4595	1.2800	1.1970
54	1.2639	68.5	1.0290	0.1834	1.3040	2.0449	1.4210	0.5543	1.1020	1.2796	1.2080	0.3651	1.3280	1.4364	1.2700	1.1960
55	1.2475	67.0	1.0210	0.1920	1.2940	2.0058	1.4010	0.5832	1.0760	1.2626	1.1860	0.3836	1.3040	1.4141	1.2600	1.1950
56	1.2319	65.5	1.0130	0.2010	1.2840	1.9680	1.3810	0.6137	1.0490	1.2464	1.1620	0.4030	1.2790	1.3928	1.2500	1.1940
57	1.2170	64.0	1.0040	0.2103	1.2740	1.9315	1.3600	0.6458	1.0220	1.2310	1.1390	0.4234	1.2540	1.3723	1.2400	1.1930
58	1.2028	62.5	0.9956	0.2201	1.2640	1.8960	1.3390	0.6798	0.9944	1.2162	1.1150	0.4449	1.2280	1.3526	1.2290	1.1920
59	1.1892	61.0	0.9864	0.2302	1.2530	1.8618	1.3180	0.7159	0.9666	1.2022	1.0900	0.4676	1.2020	1.3337	1.2180	1.1910
60	1.1763	59.5	0.9770	0.2408	1.2420	1.8285	1.2960	0.7541	0.9384	1.1887	1.0660	0.4914	1.1760	1.3155	1.2070	1.1890
61	1.1640	58.0	0.9672	0.2519	1.2310	1.7962	1.2740	0.7948	0.9099	1.1759	1.0410	0.5167	1.1490	1.2980	1.1950	1.1880
62	1.1523	56.5	0.9570	0.2635	1.2190	1.7648	1.2510	0.8383	0.8810	1.1637	1.0150	0.5434	1.1210	1.2812	1.1830	1.1860
63	1.1411	55.0	0.9465	0.2756	1.2060	1.7343	1.2280	0.8848	0.8517	1.1520	0.9897	0.5718	1.0930	1.2650	1.1710	1.1850
64	1.1305	53.6	0.9356	0.2884	1.1930	1.7046	1.2050	0.9346	0.8220	1.1409	0.9636	0.6020	1.0640	1.2494	1.1590	1.1830
65	1.1203	52.1	0.9243	0.3018	1.1800	1.6757	1.1810	0.9883	0.7921	1.1303	0.9373	0.6342	1.0350	1.2344	1.1460	1.1820
66	1.1107	50.6	0.9125	0.3159	1.1660	1.6475	1.1570	1.0460	0.7617	1.1202	0.9106	0.6687	1.0050	1.2199	1.1330	1.1800
67	1.1016	49.2	0.9003	0.3308	1.1520	1.6200	1.1320	1.1090	0.7311	1.1105	0.8835	0.7056	0.9744	1.2060	1.1200	1.1780
68	1.0929	47.7	0.8876	0.3465	1.1370	1.5931	1.1070	1.1780	0.7000	1.1014	0.8561	0.7454	0.9433	1.1926	1.1060	1.1760
69	1.0846	46.2	0.8743	0.3632	1.1210	1.5668	1.0820	1.2530	0.6687	1.0927	0.8285	0.7884	0.9115	1.1796	1.0910	1.1740
70	1.0768	44.8	0.8604	0.3810	1.1050	1.5411	1.0560	1.3350	0.6370	1.0844	0.8005	0.8350	0.8791	1.1672	1.0760	1.1720
71	1.0695	43.3	0.8460	0.4000	1.0880	1.5159	1.0290	1.4260	0.6049	1.0766	0.7722	0.8858	0.8460	1.1552	1.0610	1.1700
72	1.0625	41.8	0.8308	0.4202	1.0700	1.4911	1.0020	1.5280	0.5726	1.0692	0.7435	0.9414	0.8121	1.1437	1.0460	1.1670
73	1.0559	40.3	0.8148	0.4420	1.0510	1.4668	0.9745	1.6420	0.5399	1.0622	0.7146	1.0030	0.7775	1.1325	1.0300	1.1650
74	1.0497	38.7	0.7979	0.4655	1.0320	1.4429	0.9464	1.7710	0.5069	1.0556	0.6855	1.0710	0.7421	1.1218	1.0130	1.1620
75	1.0439	37.2	0.7801	0.4911	1.0110	1.4194	0.9177	1.9180	0.4735	1.0494	0.6560	1.1470	0.7059	1.1115	0.9950	1.1590
76	1.0385	35.6	0.7613	0.5189	0.9886	1.3961	0.8884	2.0880	0.4399	1.0435	0.6262	1.2330	0.6688	1.1016	0.9767	1.1550
77	1.0335	34.0	0.7412	0.5496	0.9650	1.3731	0.8584	2.2860	0.4059	1.0380	0.5963	1.3300	0.6306	1.0920	0.9576	1.1520
78	1.0288	32.4	0.7197	0.5836	0.9398	1.3503	0.8276	2.5220	0.3717	1.0329	0.5661	1.4420	0.5914	1.0829	0.9374	1.1480
79	1.0244	30.7	0.6967	0.6216	0.9127	1.3277	0.7961	2.8060	0.3371	1.0282	0.5357	1.5730	0.5510	1.0740	0.9162	1.1440
80	1.0204	29.0	0.6717	0.6647	0.8833	1.3051	0.7638	3.1560	0.3023	1.0238	0.5051	1.7290	0.5094	1.0656	0.8937	1.1390
81	1.0168	27.2	0.6445	0.7142	0.8513	1.2825	0.7305	3.5980	0.2673	1.0197	0.4744	1.9180	0.4664	1.0575	0.8697	1.1340
82	1.0135	25.3	0.6146	0.7722	0.8160	1.2598	0.6961	4.1740	0.2321	1.0161	0.4436	2.1520	0.4217	1.0497	0.8438	1.1280
83	1.0106	23.3	0.5813	0.8417	0.7767	1.2369	0.6606	4.9540	0.1968	1.0127	0.4129	2.4530	0.3753	1.0423	0.8156	1.1220
84	1.0080	21.3	0.5436	0.9276	0.7321	1.2135	0.6238	6.0700	0.1616	1.0097	0.3824	2.8560	0.3268	1.0352	0.7854	1.1140
85	1.0057	19.0	0.5001	1.0390	0.6805	1.1895	0.5856	7.7810	0.1267	1.0071	0.3525	3.4280	0.2758	1.0284	0.7494	1.1050

MA	Fratio	Amin	L1	L2	C2	W2	L3	L4	C4	W4	L5	L6	C6	W6	L7	C8

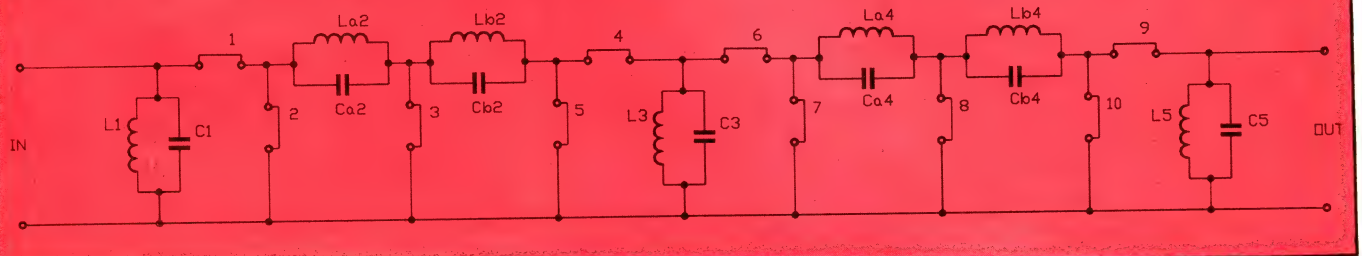
C 08 20 c DUAL

Adapted from R.Saal and E.Ulbrich, "On the Design of Filters by Synthesis ", IRE Trans Circuit Theory, Dec 1958

tuned to the centre frequency.

Armed with the information in the above table we can set about designing the location of the tuning links. You will find that the best idea is to arrange to be able to short circuit all tuned circuits except the one on which you are working, in order to eliminate the signal that they can pick up from your tuning loop, which is another reason why you have to design the location of your tuning links carefully. The resultant circuit is shown in Figure 4.12 in which 10 links are needed. It is possible to design links 1 & 2, 4 & 5, 6 & 7, and 9 & 10 using only 3 pads so that they can effectively be used as 3 position switches, connected to the tuned circuit, connected to earth, or open cir-

Figure 4.12. Circuit of elliptic BP filter for use at the output of a low powered transmitter. Passband is 28.0 to 29.7 MHz with a ripple of 0.1 dB. Attenuation is greater than 60 dB for all frequencies below 27.0 MHz and above 30.8 MHz. The links are used during tuning.



C 09 20 NORMAL

MA	Fratio	Amin	C1	C2	L2	M2	C3	C4	L4	M4	C5	C6	L6	M6	C7	C8	L8	M8	C9
51	1.2868	85.7	1.2820	0.0781	1.3220	3.1119	1.8540	0.4671	1.0710	1.4137	1.5440	0.6176	0.9595	1.2990	1.6310	0.2869	1.1090	1.7727	1.1050
52	1.2690	83.9	1.2790	0.0819	1.3180	3.0437	1.8370	0.4908	1.0520	1.3914	1.5140	0.6501	0.9377	1.2808	1.6060	0.3014	1.0960	1.7395	1.0940
53	1.2521	82.1	1.2750	0.0858	1.3140	2.9778	1.8200	0.5155	1.0330	1.3702	1.4840	0.6843	0.9155	1.2635	1.5810	0.3166	1.0830	1.7075	1.0830
54	1.2361	80.3	1.2720	0.0899	1.3100	2.9140	1.8020	0.5414	1.0140	1.3498	1.4530	0.7207	0.8930	1.2469	1.5550	0.3324	1.0700	1.6766	1.0720
55	1.2208	78.6	1.2680	0.0942	1.3050	2.8522	1.7840	0.5685	0.9939	1.3303	1.4210	0.7580	0.8703	1.2312	1.5290	0.3490	1.0560	1.6469	1.0600
56	1.2062	76.9	1.2650	0.0986	1.3010	2.7923	1.7650	0.5969	0.9737	1.3117	1.3890	0.7979	0.8472	1.2163	1.5030	0.3664	1.0420	1.6183	1.0480
57	1.1924	75.2	1.2610	0.1032	1.2960	2.7341	1.7460	0.6268	0.9531	1.2938	1.3570	0.8401	0.8239	1.2020	1.4760	0.3846	1.0280	1.5907	1.0360
58	1.1792	73.5	1.2570	0.1080	1.2910	2.6775	1.7260	0.6582	0.9321	1.2767	1.3240	0.8847	0.8003	1.1884	1.4480	0.4037	1.0130	1.5640	1.0230
59	1.1666	71.8	1.2530	0.1131	1.2860	2.6225	1.7060	0.6912	0.9108	1.2603	1.2910	0.9321	0.7764	1.1755	1.4200	0.4238	0.9974	1.5382	1.0100
60	1.1547	70.1	1.2480	0.1183	1.2810	2.5690	1.6860	0.7261	0.8891	1.2446	1.2570	0.9825	0.7523	1.1632	1.3920	0.4449	0.9816	1.5133	0.9959
61	1.1434	68.5	1.2440	0.1238	1.2750	2.5168	1.6660	0.7629	0.8670	1.2296	1.2230	1.0360	0.7279	1.1514	1.3630	0.4671	0.9654	1.4891	0.9817
62	1.1326	66.8	1.2390	0.1296	1.2690	2.4659	1.6450	0.8019	0.8446	1.2151	1.1890	1.0930	0.7033	1.1403	1.3340	0.4906	0.9487	1.4658	0.9671
63	1.1223	65.2	1.2340	0.1356	1.2630	2.4161	1.6230	0.8433	0.8217	1.2013	1.1540	1.1550	0.6785	1.1297	1.3050	0.5155	0.9315	1.4432	0.9520
64	1.1126	63.5	1.2290	0.1420	1.2570	2.3675	1.6000	0.8873	0.7985	1.1880	1.1190	1.2210	0.6534	1.1196	1.2750	0.5418	0.9138	1.4212	0.9364
65	1.1034	61.9	1.2230	0.1487	1.2500	2.3199	1.5780	0.9342	0.7749	1.1753	1.0830	1.2920	0.6281	1.1100	1.2440	0.5698	0.8956	1.4000	0.9202
66	1.0946	60.2	1.2170	0.1557	1.2430	2.2732	1.5550	0.9844	0.7509	1.1631	1.0470	1.3690	0.6026	1.1009	1.2130	0.5995	0.8768	1.3793	0.9034
67	1.0864	58.6	1.2110	0.1631	1.2360	2.2274	1.5310	1.0380	0.7265	1.1514	1.0110	1.4530	0.5769	1.0923	1.1820	0.6313	0.8574	1.3592	0.8860
68	1.0785	56.9	1.2050	0.1710	1.2280	2.1824	1.5060	1.0960	0.7017	1.1403	0.9739	1.5440	0.5510	1.0841	1.1500	0.6653	0.8374	1.3397	0.8679
69	1.0711	55.2	1.1980	0.1793	1.2200	2.1381	1.4810	1.1590	0.6764	1.1296	0.9367	1.6440	0.5250	1.0764	1.1180	0.7019	0.8167	1.3208	0.8491
70	1.0642	53.6	1.1910	0.1882	1.2110	2.0945	1.4550	1.2270	0.6507	1.1193	0.8992	1.7540	0.4987	1.0691	1.0850	0.7413	0.7953	1.3023	0.8294
71	1.0576	51.9	1.1840	0.1977	1.2020	2.0514	1.4290	1.3010	0.6245	1.1095	0.8614	1.8760	0.4723	1.0622	1.0520	0.7840	0.7732	1.2844	0.8089
72	1.0515	50.2	1.1760	0.2078	1.1920	2.0089	1.4010	1.3820	0.5979	1.1002	0.8233	2.0130	0.4457	1.0558	1.0180	0.8304	0.7503	1.2669	0.7875
73	1.0457	48.5	1.1670	0.2187	1.1820	1.9667	1.3730	1.4710	0.5708	1.0912	0.7849	2.1660	0.4190	1.0497	0.9841	0.8812	0.7265	1.2498	0.7650
74	1.0403	46.8	1.1580	0.2305	1.1710	1.9249	1.3440	1.5710	0.5432	1.0827	0.7463	2.3390	0.3922	1.0440	0.9494	0.9370	0.7017	1.2332	0.7414
75	1.0353	45.1	1.1480	0.2433	1.1590	1.8834	1.3140	1.6820	0.5150	1.0746	0.7073	2.5380	0.3652	1.0387	0.9141	0.9988	0.6760	1.2170	0.7165
76	1.0306	43.3	1.1370	0.2572	1.1460	1.8420	1.2830	1.8070	0.4862	1.0668	0.6681	2.7680	0.3381	1.0337	0.8782	1.0680	0.6491	1.2011	0.6902
77	1.0263	41.5	1.1260	0.2724	1.1320	1.8006	1.2510	1.9500	0.4569	1.0595	0.6287	3.0360	0.3110	1.0291	0.8414	1.1460	0.6211	1.1856	0.6622
78	1.0223	39.6	1.1130	0.2893	1.1170	1.7592	1.2180	2.1150	0.4268	1.0525	0.5891	3.3550	0.2838	1.0249	0.8048	1.2340	0.5917	1.1704	0.6323
79	1.0187	37.7	1.0990	0.3081	1.1000	1.7175	1.1830	2.3080	0.3961	1.0459	0.5493	3.7410	0.2564	1.0209	0.7669	1.3360	0.5607	1.1555	0.6004
80	1.0154	35.8	1.0840	0.3292	1.0820	1.6755	1.1460	2.5380	0.3645	1.0397	0.5094	4.2160	0.2291	1.0174	0.7286	1.4550	0.5281	1.1409	0.5658
81	1.0125	33.8	1.0670	0.3534	1.0610	1.6328	1.1075	2.8170	0.3321	1.0339	0.4693	4.8170	0.2019	1.0142	0.6895	1.5970	0.4935	1.1265	0.5281
82	1.0098	31.7	1.0470	0.3814	1.0380	1.5893	1.0670	3.1660	0.2986	1.0284	0.4293	5.5990	0.1746	1.0113	0.6497	1.7700	0.4567	1.1124	0.4868
83	1.0075	29.5	1.0250	0.4145	1.0110	1.5447	1.0240	3.6160	0.2641	1.0233	0.3894	6.6600	0.1476	1.0087	0.6090	1.9860	0.4172	1.0985	0.4407
84	1.0055	27.1	0.9995	0.4548	0.9794	1.4984	0.9782	4.2230	0.2282	1.0186	0.3496	8.1750	0.1208	1.0065	0.5676	2.2680	0.3747	1.0848	0.3886
85	1.0038	24.6	0.9688	0.5054	0.9411	1.4499	0.9284	50.9300	0.1909	1.0143	0.3103	10.5000	0.0944	1.0046	0.5253	2.6550	0.3283	1.0711	0.3281

MA	Fratio	Amin	L1	L2	C2	M2	L3	L4	C4	M4	L5	L6	C6	M6	L7	L8	C8	M8	L9

C 09 20 DUAL

Adapted from R.Saal and E.Ulbrich, "On the Design of Filters by Synthe sis ", IRE Trans Circuit Theory, Dec 1958

cuit.

Tuning elliptic LC filters

Since elliptic LC filters are used mostly at RF, the inductors are usually air-cored. This means that tuning is done using the signal generator connected to a single turn loop mounted just close enough to the "earthy" end of the inductor being tuned to get a useful reading on the meter. Notice the word "mounted" was used, not "held".

Since you are trying to detect a fairly sensitive maximum reading, it is essential that the amount of RF being injected into the circuit be constant during the test. This is just not possible if you wave the tuning loop around in your hand. Also, the filter itself has to be firmly held down during tuning so that the tuning process does not change its position with respect to the tuning loop. For frequencies above about 10 MHz, it is best to mount the filter where it is to be used so that any stray capacitances e.g: to a metal enclosure, are as close as possible to their final value. Of course, you have to leave the lid off or you can't tune the thing.

Since the the only way to change the inductance of air-wound coils is by compressing or expanding them, each time a change is made the signal generator frequency is slowly swept across the design frequency for that tuned circuit to make sure that the meter maximum occurs at the correct frequency. If the maximum occurs above the design frequency, the coil needs to be compressed and the resonant frequency checked again; if the frequency is low, the coil needs to be stretched to lower its inductance.

At 28 MHz, where inductances an be as low as 13 nH, the 'coils' consist of a single turn and the only easy way of adjusting them is to squash them into ellipses. This tends to lower their Q, but short of remaking the coil with a different diameter, there isn't much you can do. Those more senior members amongst the readers will remember using either a small piece of brass or of high frequency ferrite placed near such coils to change their inductance, but such simple methods seem to have fallen into disrepute.

For all elliptic filters, the capacitors must be as close as possible to the design value since some of them control the frequency response in the passband and they can't be tuned, and the rest control the notch frequencies. At high frequencies, where the capacitor values can be only 100 pF or so, some estimate has to be made of the magnitude of the stray capacitance that is to be expected at the position of each capacitor on the printed circuit board. This is usually in the range 2 to 6 pF, but obviously the lower the better.

So the capacitances of the capacitors that you use have to be 2 to 6 pF lower than the calculated values. In extreme cases this difference can be as large as 10 pF, particularly with double sided printed circuit board. So the moral is to use the shortest conductor lines that you can, consistent with isolation of adja-

– to page 62 ▷

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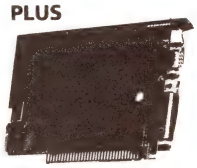

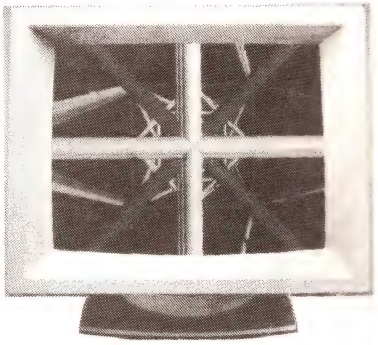

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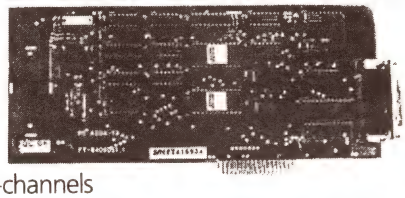

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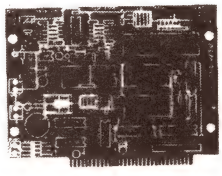

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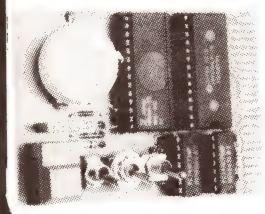

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Inductors — unravelling a few myths

John Day VK3ZJF

As an accompaniment to the series of articles on the design of LC filters by Jack Middlehurst (which commenced in the October 1987 issue), this dissertation has been prepared to give readers an insight into how to design the actual inductor once the filter has been designed.

THE DESIGN AND CONSTRUCTION of inductive components has for many, enthusiasts and professionals alike, remained somewhat of a "black art", despite the many books and magazine articles published which discuss some aspect or another of the design of inductors. In this article, we will try to take the black art out of inductor design and turn it into somewhat more of science for you. This means that, when you design a coil to do a job or have certain characteristics, it will have those characteristics, or at least closely approach them.

An inductor for use in the construction of a filter should possess several important characteristics:

- It should have a quality factor or "Q" as high as possible, in other words, it should have as little loss as possible.
- It should be well shielded to prevent stray radiation and pickup, thus avoiding unwanted coupling between inductors as well as noise pickup.
- It should be relatively free of "microphonics". Microphonics are changes in characteristics due to external mechanical influences and low frequency external noise which cause the component to act as a microphone.
- It should be easy to design and readily duplicated.

Over the range of frequencies involved, several different types of construction can be used to achieve these goals. Each method has its own advantages over a particular frequency range. We will examine three methods: toroidal cores, solenoid coils with or without cores, and pot cores.

Toroidal inductors

One of the most useful and easily made type of inductor is the toroidal cored type. The toroid is a "donut" shaped core made from wound-up steel tape, ferrite or powdered iron.

Tape-wound cores are generally used for audio and ac power applications such as audio transformers and ac mains transformers. Ferrite cores are most popular for energy storage inductors and transformers in switched mode power supplies as well as for RFI/EMI suppression. For our application, powdered iron is the material of choice.

Toroids are easy to design with, having the following features:

- Almost total shielding of the winding and immunity to external fields due to the shape of the magnetic circuit,
- Vast range of types available from 1.2 mm to 125 mm in outside diameter.

John Day is the Technical Director of Stewart Electronic Components Pty Ltd, who distribute the ferromagnetic products of Amidon Associates Inc. and Philips, along with inductive products from J. W. Miller. Stewart Electronic Components are located at 44 Stafford St, Huntingdale (PO Box 281 Oakleigh) 3166 Vic. (03)543 3733.

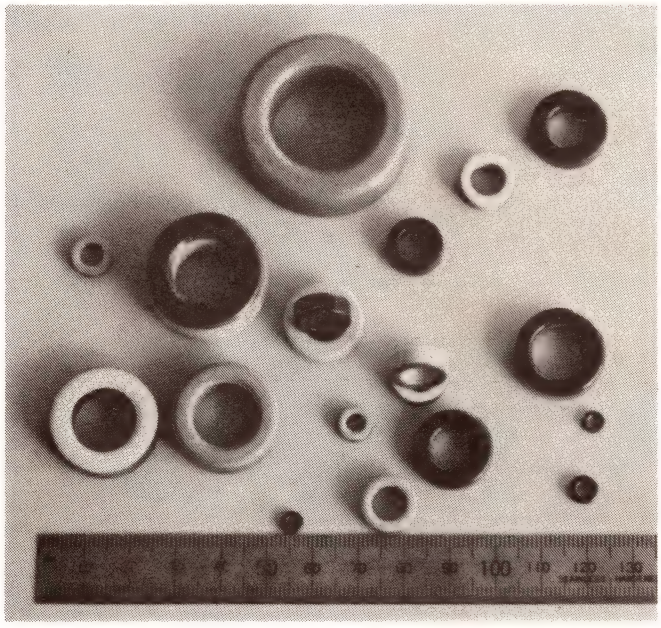


Figure 1. A selection of toroidal cores.

- Well defined magnetic properties which are well specified in manufacturers data sheets.
- Low cost.

Figure 1 shows a variety of toroidal cores of different sizes and material. The powdered iron cores are all colour coded to indicate the material from which they are made. Most ferrite cores are uncoded, but some manufacturers do use a coloured coating if the cores are ordered that way. Unfortunately, there is little or no consistency of colour coding between manufacturers.

On the facing page is a "short form" data page which, in conjunction with some information on the actual materials, gives us all the information we need to design our toroidal inductor. Let us now examine this information.

The major part of the page is taken up by the parts table. Across the top of this table is the type of material, it's colour code, which appears on each core, the permeability (μ – or, "mew") of the material and the basic frequency range for the material. More details on the materials are given below. Down the left hand side is the core size, from T400A, a 102 mm monster of a core at the top, down to the diminutive 3.2 mm T12 size at the bottom.

On the top left of the page is the table of mechanical and magnetic dimensions. The first three figures are self explanatory and the last three are the magnetic dimensions. The Mean Path Length or magnetic length of the core is equal to the mean ▷

Iron-Powder Toroidal Cores

AMIDON Iron-Powder Toroidal Cores

Physical Dimensions — Iron-Power Toroidal Cores

CORE SIZE	Outer Diam. (mm)	Inner Diam. (mm)	Height (mm)	Mean Path L (cm)	Cross Sect. A (cm²)	Volume V (cm³)
T12	3.18	1.57	1.27	0.75	0.01	0.0075
T16	4.06	1.98	1.52	0.95	0.016	0.015
T20	5.08	2.24	1.78	1.15	0.025	0.029
T25	6.48	3.05	2.44	1.50	0.042	0.063
T30	7.80	3.84	3.25	1.83	0.065	0.115
T37	9.53	5.21	3.25	2.32	0.07	0.153
T44	11.20	5.82	4.04	2.67	0.107	0.284
T50	12.7	7.70	4.83	3.20	0.121	0.374
T68	17.50	9.40	4.83	4.24	0.193	0.803
T80	20.20	12.60	6.35	5.15	0.242	1.25
T94	23.90	14.20	7.92	6.00	0.385	2.27
T106	26.90	14.50	11.10	6.50	0.69	4.56
T130	33.00	19.80	11.10	8.29	0.733	6.08
T157	34.90	24.10	14.50	10.05	1.14	11.30
T184	46.70	24.10	18.00	11.12	2.04	21.90
T200	50.80	31.80	14.00	12.97	1.33	17.30
T200A	50.80	31.80	25.40	12.97	2.42	31.40
T225	57.20	35.60	14.00	14.59	1.50	21.80
T225A	57.20	35.60	25.40	14.59	2.73	39.80
T300	77.20	49.00	12.70	19.82	1.79	35.50
T300A	77.20	49.00	25.40	19.82	3.58	71.00
T400	102.00	57.20	16.50	24.94	3.66	91.30
T400A	102.00	57.20	33.00	24.94	7.32	183.00

AMIDON Associates, INC.

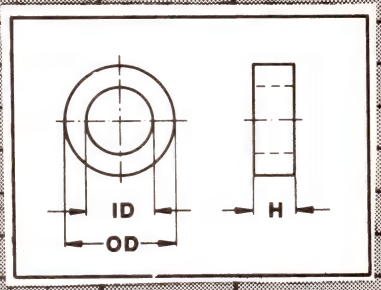
Number of Turns vs. Wire Size and Core Size

Approximate maximum number of turns-single layer wound-enamelled wire

Wire Size AWG	Core Size									
	T200	T130	T106	T94	T80	T68	T50	T37	T25	T12
10	33	20	12	12	10	6	4	1	—	—
12	43	25	16	16	14	9	6	3	—	—
14	54	32	21	21	18	13	8	5	1	—
16	69	41	28	28	24	17	13	7	2	—
18	88	53	37	37	32	23	18	10	4	1
20	111	67	47	47	41	29	23	14	6	1
22	140	86	60	60	53	38	30	19	9	2
24	177	109	77	77	67	49	39	25	13	4
26	223	137	97	97	85	63	50	33	17	7
28	281	173	123	123	108	80	6	42	23	9
30	357	217	154	154	136	101	81	54	29	13
32	439	272	194	194	171	127	103	68	38	17
34	557	346	247	247	218	162	132	88	49	23
36	683	424	304	304	268	199	162	108	62	30
38	875	544	389	389	344	256	209	140	80	39
40	1103	687	492	492	434	324	264	178	102	51

HOW TO ORDER —:

Core Size	26-mix yl/wh μ = 75 0 -1.0 MHz	3-mix grey μ = 35 .05 - 0.5 MHz	15-mix rd/wh μ = 25 0.1 - 2 MHz	1-mix blue μ = 20 0.5 - 5 MHz	2-mix red μ = 10 1 - 30 MHz	6-mix yellow μ = 8 2 - 50 MHz	10-mix black μ = 6 10 - 100 MHz	12-mix gr/wh μ = 3 20 - 200 MHz	0-mix tan μ = 1 50 - 300 MHz
T400A—	FC300 *AI 2600*				FC301 *AI 360*				
T400—	FC302 *AI 1320*				FC303 *AI 185*				
T300A—	FC304 *AI 1600*				FC305 *AI 228*				
T300—	FC306 *AI 825*				FC307 *AI 115*				
T225A—	FC308 *AI 1600*				FC309 *AI 215*				
T225—	FC310 *AI 950*	FC311 *AI 425*			FC312 *AI 120*	FC313 *AI 100*			
T200A—	FC314 *AI 1550*	FC442 *AI 460*		FC443 *AI 455*	FC315 *AI 218*	FC316 *AI 180*			
T200—	FC317 *AI 895*	FC318 *AI 425*		FC319 *AI 250*	FC320 *AI120*	FC321 *AI100*			
T184—	FC322 *AI 1640*	FC323 *AI 720*		FC324 *AI 500*	FC325 *AI 240*	FC326 *AI 195*			
T157—	FC327 *AI 970*	FC328 *AI 420*	FC329 *AI 360*	FC330 *AI 320*	FC331 *AI 140*	FC332 *AI 115*			
T130—	FC333 *AI 785*	FC334 *AI 350*	FC335 *AI 250*	FC336 *AI 200*	FC337 *AI 110*	FC38 *AI 96*			FC339 *AI 15*
T106—	FC340 *AI 900*	FC341 *AI 450*	FC342 *AI 345*	FC343 *AI 325*	FC344 *AI 135*	FC345 *AI 116*			FC3346 *AI 19*
T94—	FC347 *AI 590*	FC348 *AI 248*	FC349 *AI 200*	FC350 *AI 160*	FC351 *AI 84*	FC352 *AI 70*	FC353 *AI 58*	FC354 *AI 32*	FC355 *AI 10.6*
T80—	FC356 *AI 450*	FC357 *AI 180*	FC358 *AI 170*	FC359 *AI 115*	FC360 *AI 55*	FC361 *AI 45*	FC362 *AI 32*	FC363 *AI 22*	FC364 *AI 8.5*
T68—	FC365 *AI 420*	FC366 *AI 195*	FC367 *AI 180*	FC368 *AI 115*	FC369 *AI 57*	FC370 *AI 47*	FC371 *AI 32*	FC372 *AI 21*	FC373 *AI 7.5*
T50—	FC374 *AI 320*	FC375 *AI 175*	FC376 *AI 135*	FC377 *AI 100*	FC378 *AI 49*	FC379 *AI 40*	FC380 *AI 31*	FC381 *AI 18*	FC382 *AI 6.4*
T44—	FC383 *AI 360*	FC384 *AI 180*	FC385 *AI 160*	FC386 *AI 105*	FC387 *AI 52*	FC388 *AI 42*	FC389 *AI 33*	FC390 *AI 19*	FC391 *AI 6.5*
T37—	FC392 *AI 275*	FC393 *AI 120*	FC394 *AI 90*	FC395 *AI 80*	FC396 *AI 40*	FC397 *AI 30*	FC398 *AI 25*	FC399 *AL 15*	FC400 *AI 4.9*
T30—	FC401 *AI 325*	FC402 *AI 140*	FC403 *AI 93*	FC404 *AI 85*	FC405 *AI 43*	FC406 *AI 36*	FC407 *AI 25*	FC408 *AI 16*	FC409 *AI 6.0*
T25—		FC410 *AI 100*	FC411 *AI 100*	FC412 *AI 70*	FC413 *AI 34*	FC414 *AI 27*	FC415 *AI 19*	FC416 *AI 12*	FC417 *AI 4.5*
T20—		FC418 *AI 90*	FC419 *AI 65*	FC420 *AI 52*	FC421 *AI 27*	FC422 *AI 22*	FC423 *AI 16*	FC424 *AI 10*	FC425 *AI 3.5*
T16—		FC426 *AI 61*	FC427 *AI 55*	FC428 *AI 44*	FC429 *AI 22*	FC430 *AI 19*	FC431 *AI 13*	FC432 *AI 8*	FC433 *AI 3.0*
T12—		FC434 *AI 60*	FC435 *AI 50*	FC436 *AI 48*	FC437 *AI 20*	FC438 *AI 17*	FC439 *AI 12*	FC440 *AI 7*	FC441 *AI 3.0*



Number shown in reverse STEWART stock number. —always order by this number only—
To obtain **AMIDON** part number add mix number to core size i.e. T400A-26
AI value shown under stock number (μH / 100 turns)

$$\text{Turns} = 100\sqrt{\frac{\text{desired L (uh)}}{A_L\ (\text{uh}/100\text{t})}}$$

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Iron-Powder Toroidal Cores

AMIDON Iron-Powder Toroidal Cores Con't

MATERIALS

Mix 3 (35 permeability) A carbonyl 'HP' iron-powder material having excellent stability and good 'Q' for the lower frequencies from 50 KHz.

Mix 15 (25 permeability) A carbonyl 'GS6' iron-powder material offering good stability for commercial broadcast frequencies where good 'Q' and high order of permeability must be maintained.

Mix 1 (20 permeability) A carbonyl 'C' iron-powder material very similar to the **mix 3** material, but has a higher volume resistivity and offers beter stability than the **mix 3** material.

Mix 2 (10 permeability) A carbonyl 'E' iron-powder material having high volume resistivity and offers high 'Q' for the 1 MHz to 30 MHz frequency band. Most widely used of all iron-powder materials.

Mix 6 (8 permeability) A carbonyl 'SF' iron-powder material very similar to the **mix 2** material, but has an improved 'Q' for the higher frequencies to 50 MHz. Higher cost than **mix 2** material.

Mix 10 (6 permeability) A carbonyl material offering high 'Q' for frequencies to 100 MHZ.

Mix 12 (3 permeability) A synthetic oxide material (Irn. 8) haveing moderate 'Q' above 100 MHz.

Mix 0 (1 permeability) This material has a permeability of 1. Most commonly used for frequencies above 200 MHz.

Mix 26 (75 permeability) A hydrogen reduced material very similar to **mix 41** material, but offers extended frequency range.

Iron-Powder toroidal cores are available in numerous sizes rangeing from 0.05" to more than 5" in outer diameter. There are two basic material groups :-

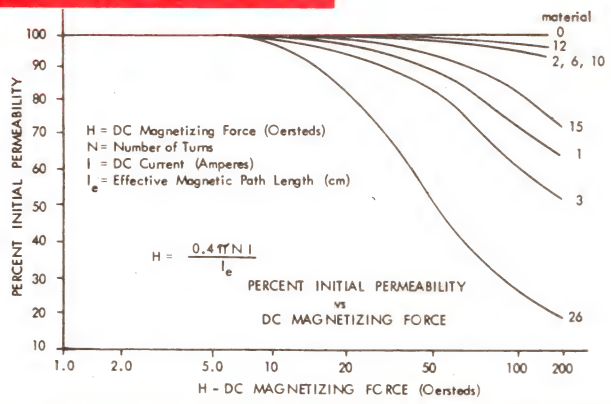
The Carbonyl Irons and the Hydrogen Reduced Irons. The Carbonyl types are especially noted for there excellent stability over a wide range of temperatures and flux levels. Their permeability range is from less than 3mu to 35 mu and can offer excellent 'Q' factors for the 50 KHz to 200 MHz frequency range. They are ideally suited for a variety of RF applications.

The frequency range specified for each material mix is especially important for tuned circuits where high 'Q' is essential. These same materials can also be used in broad-band applications where 'Q' is no longer a primary concern, therefore, be usefull to considerably higher frequencies.

The Hydrogen Reduced Irons have permeabilities ranging from 35 mu to 90 mu. Some-what lower 'Q' values should be expected from this group of cores. They are mainly used for **EMI** filters and low frequency chokes. In recent years they have been very much in demand for use in both input and output filters for **switch-mode** power supplies.

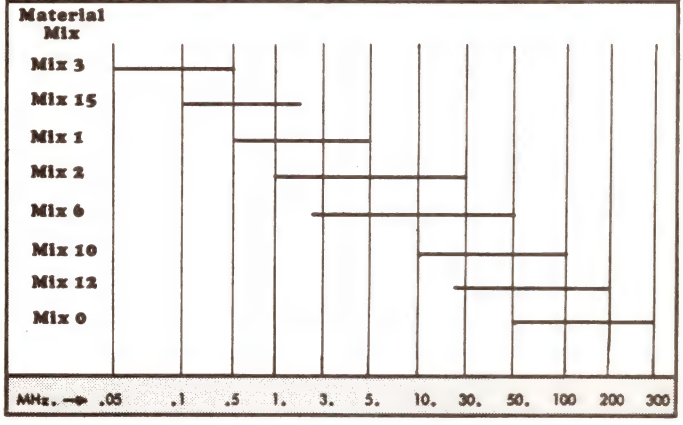
Toroidal cores, in general, are the most efficient of any core configuration. They are highly self-shielding since most of the flux lines are contained within the toroidal form. The flux lines are essentially uniform over the entire magnetic path length and consequently stay magnetic fields will have very little effect on a toroidal inductor.It is seldom necessary to shield or isolate a toroidal inductor to prevent feedback or cross-talk. Toroidal inductors simply do not like to talk to each other.

The number of turns required for a specific inductance may be calculated by using the Al value for the selected core and the formula at the botom of the HOW TO ORDER chart.



IRON—POWDER MATERIAL vs. FREQUENCY RANGE

For best 'Q', Select larger cores from the lower portion of the material range, and the smaller cores from the upper portion of the frequency range.



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circumference of a toroidal core. Cross sectional area and core volume are used in calculations involving the power handling capability of a core.

The top right of the page is taken up by a loading table. This table shows the maximum number of turns of a selection of wire sizes for each core size. These figures are for a single layer winding using enamelled wire.

Having calculated the value of inductance required and knowing the frequency range involved, you may proceed to design your toroidal inductor.

The first step is to consult the list of materials in Table 1 and select one which covers your desired frequency range. Generally speaking, cores which have a low permeability will be much more temperature stable at low frequencies, however it may be necessary to sacrifice some of our stability to build a reasonable sized inductor. Material 26 is not discussed here because it is designed for RFI/EMI suppression applications. Material 0 is not actually an iron powder, but a phenolic material with a permeability of 1 (same as air) and is often used as a former for VHF coils not needing a ferromagnetic core.

Once an appropriate material is selected, we need to select an appropriate sized core. This is done by a slightly backward process, but it does work. Let's assume that we have need for a 12 uH inductor for use in a filter at 3.5 MHz. Although mixes 1, 2 or 6 could be used for this coil, we have some mix 2 types on hand because they are so popular and we will use them in our example.

Start by evaluating the inductor built on a mid-range size core, say a T50 size of 12.7 mm outside diameter. The table shows the A1 or specific inductance in uH/100 turns under the stock number so to obtain the number of turns required, we apply this formula:

$$\text{TURNS} = 100 \sqrt{\frac{\text{desired L (uH)}}{A_L \text{ (uH/100 turns)}}}$$

In our case, the answer is 49.5 turns so we will round up and say 50 turns are required. Now consult the table of turns versus wire and core size, also known as a loading table. Looking down the T50 column, we find that we can get 50 turns of 25 AWG wire onto this core. Bear in mind that these are maximum loadings for the core and unless you are extremely careful, it is not easy to load the maximum number of turns in practice.

As the Q of an inductor is the ratio of the reactance to the resistance of the inductor, it is obviously a good idea to keep the wire size as large as possible in order to keep the resistance as low as possible, so let's try the next core size up. Applying our formula as before, we now need 46 turns on a T68 core with A1 57. Another look at the loading table shows we can get 63 turns of 26 AWG wire onto this core so we now have some room to spare.

One point worth keeping in mind is that most filter designs assume that the inductors and capacitors will have very little loss or conversely, a very high Q. In a filter, the degradation of Q in the components can result in increases in the passband insertion loss (the loss in the range of frequencies meant to be passed unattenuated). By keeping the inductor Q high and using good quality capacitors, we can optimize the performance of our filter. When designing the inductors, bear in mind that larger wire sizes and larger core sizes will give higher Q in the lower portion of the frequency range of a given material and smaller cores and smaller wire will give higher Q in the upper portion of the range.

When winding a toroid whose value has been calculated in

this way, it is well to keep in mind the conditions for which the tables apply. They should only be believed when there is little or no dc current in the winding, the winding should occupy 85% of the core circumference and the winding should not be coated or glued in place. A turn on a toroidal core is considered as being one pass through the centre of the core and half turns are thus not possible on a toroid. If you need to fix the windings, use a good quality "Q" dope or, if this is unobtainable, dissolve some expanded styrene foam in ether and use this. Most polyester and epoxy resins are not suitable for coating inductors as they tend to lower the Q fairly dramatically. Appropriate resins are available commercially, but they are expensive, have a limited lifetime and only come in 500 gram tins. Not exactly what we enthusiasts need!

When using a toroidally wound inductor in a low impedance filter, the method of mounting is not overly important. If you want to stand the toroid in its edge, then a blob of silicone sealant (e.g: Dow Corning's "Silastic") can be used to secure the core to the board. If the filter impedance is high or is used in a narrow band pass filter, the toroid is best mounted flat on the board. You can either secure the inductor to the board with some Q dope or cut a washer of pc board stock with no copper on it and clamp the inductor to the board with a nylon screw. There should not be any printed circuit copper on the board in the region under the inductor and the surrounding area.

Solenoid coils

A solenoid coil is any coil where the winding is in a straight solenoid (cylindrical) form. The common air-cored inductor found in VHF equipment is a good example of such a solenoid coil. Air cored coils of this type are best left for applications above 100 MHz. As it is not intended for the filter designs discussed by Jack Middlehurst to be used above 100 MHz, we will not discuss this type of inductor in detail. Information on calculating the inductance of an air cored solenoid can be found in the ARRL handbook, the RSGB VHF/UHF manual and the RSGB radio amateurs data book. Solenoid coils can also be wound on a non-magnetic or dielectric former into which a ferromagnetic material can be introduced. This is your common coil former set with an adjustable slug. Illustrated here are some examples of these coil former sets. (Figure 2)

Three different sizes are shown here which can be used for applications from the upper audio range to 200 MHz or so. From a perusal of the data sheet for the assemblies, you will see that the same powdered iron materials are used for the cores and shielding cups as are found in the toroids. Owing to the method of construction, the different materials have slightly different frequency ranges in this application compared to that when used in toroidal form.

The specific inductance value is quoted in much the same way as toroidal cores. An assembly of this type has its highest Q when the slug is near its deepest penetration. When designing the inductor, calculate the inductance based on 90% of the A1 value quoted in the table. This allows for some adjustment, with the slug, above and below the inductance value actually wound on.

Freq Range	Mix	Permeability	Comments
.05 – .5 MHz	3	35	Good low frequency cores with excellent stability
.1 – 2 MHz	15	25	Offers good stability at broadcast band with high Q
0.5 – 5 MHz	1	20	Excellent stability
1 – 30 MHz	2	10	The most popular iron powder material, offering good Q over the whole HF range
2 – 50 MHz	6	8	Similar to mix 2 but with extended upper frequency range at higher cost
10 – 100 MHz	10	6	High Q for use up to 100 MHz
20 – 200 MHz	12	3	Best for use over 100 MHz but also suited for low value inductors at lower frequencies

TABLE 1. Iron powder material characteristics.

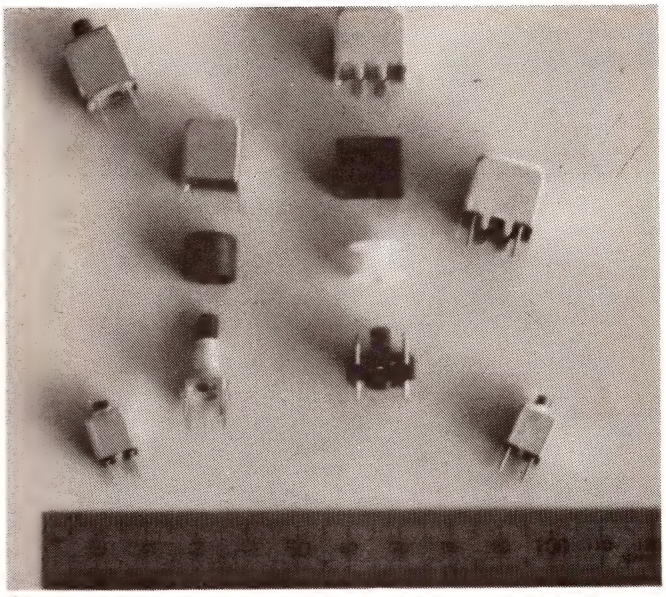


Figure 2. Some examples of shielded coil former assemblies.

Some filter designs are best implemented with an adjustable element to allow the response to be optimized, particularly at higher frequencies where stray inductance and capacitance can have a major effect. Sometimes it is practical to use trimmer capacitors, but in other applications, such as where the capacitance values are high or in coupled resonator filters matched with tapped capacitive dividers, the inductor should be made variable so that the capacitance ratio stays constant.

Assembly types L33 and L43 have the former tube glued into the base and thus it is best for the hobbyist to put the winding on carefully by hand. It is suggested that you use wire with a solderable enamel which is generally available in small quantities from your local electronics emporium. When winding a coil of this type, I use the following procedure:

1. Mark one of the pins on the base with a blue marker to signify the bottom or "cold" end of the coil (that end connected to "common" or ground).

2. Mark another pin with a red marker to signify the top or "hot" end of the coil (that end which will not be connected to "common" or ground).

3. Wrap one turn of the wire around the cold end pin and taking the wire along the guide slots in the base and thus onto the former, commence the winding.

4. If the winding is to be of fine wire or of many turns, a small blob of nail varnish can be used to keep the start of the winding in place.

5. Wind the wire onto the former keeping it well tensioned and with each turn hard against the previous one so that the turns lay evenly one beside the other.

6. At the top end, another blob of nail varnish may be used to secure the winding.

7. Taking the wire via the guide slot, pass it around the other marked pin for one turn.

8. Using a small pair of wire cutters, cut the wire as close as possible to the pin.

9. With a hot soldering iron and using fine solder (e.g: 20 or 22 gauge), solder the wires to the pins. ▷

Iron Powder Shielded Coil Former Kits

AMIDON L33 Series Shielded Coil Form Assemblies

Sub-Miniature Adjustable Inductors easly Wound on Shielded Coil Form Assemblies.

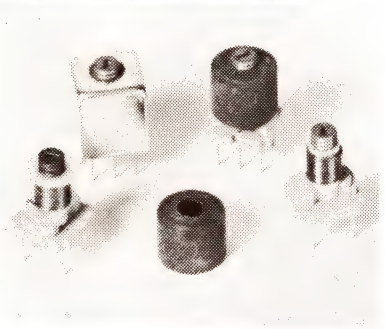
The AMIDON L33 series tunes from both top and bottom and is supplied as a kit comprising —; Shielding can (copper tin plated) -Cup core for magnetic shielding of same material as core for maximum efficiency at operating frequency - Core to provide adjustment of inductance - Nylon winding bobbin -Moulded plastic base with 5 contacts to accommodate centre tapped coil ON one winding only. — Five pieces in all.

They are most efficient when tuning slug is set at maximum L. For tuning flexibility calculate so that slug will be about 90% maximum L when at operating frequency.

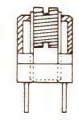
Solid magnet wire may be substituted for Litz wire, but somewhat lower 'Q' may result.

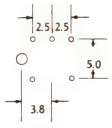
Frequency Range 10kHz to 200mHz Inductance Range .08 to 180uH.

$$\text{Turns} = 100\sqrt{\frac{\text{desired 'L' (uh)}}{90\%\ A_L\ (\text{ uh/100 turns })}}$$



STOCK No.	AMIDON No.	Iron Grade & Colour Code	Frequency Range	A_L(μH/100t) at Max. L	L ratio Max. to Min.	Typical Winding (mid-freq.) Wire	Turns	LμH	Q Max.
FC600	L33-1	1 — Blue	300kHz - 1mHz	76	1.7 / 1	3/44	75	42.5	80
FC601	L33-2	2 — Red	1 - 10mHz	68	1.5 / 1	9/44	40	10.9	90
FC602	L33-3	3 — Gray	100 - 500kHz	80	1.8 / 1	3/44	150	180	70
FC603	L33-6	6 — Yellow	10 — 50mHz	60	1.5/1	26	7	0.36	100
FC604	L33-10	10 — Black	25 — 100mHz	54	1.4/1	26	5	0.18	120
FC605	L33-12	12 — Green	50 — 200mHz	48	1.3/1	26	3	0.08	130

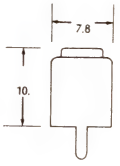


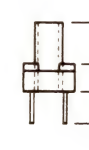


Terminal Spacing

Cup Core

Threaded Core





Actual Size

AMIDON L43 Series Shielded Coil Form Assemblies

Miniature Adjustable Inductors easly Wound on Shielded Coil Form Assemblies.

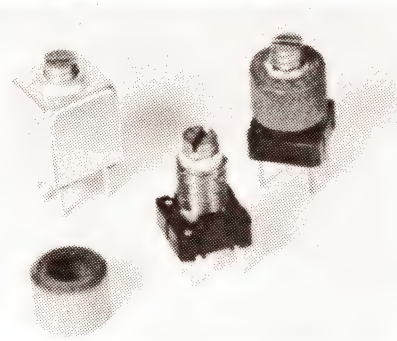
The AMIDON L43 series tunes from both top and bottom and is supplied as a kit comprising —; Shielding can (copper tin plated) -Cup core for magnetic shielding of same material as core for maximum efficiency at operating frequency - Core to provide adjustment of inductance - Nylon winding bobbin -Moulded plastic base with 5 contacts to accommodate centre tapped coil ON one winding only. — Five pieces in all.

They are most efficient when tuning slug is set at maximum L. For tuning flexibility calculate so that slug will be about 90% maximum L when at operating frequency.

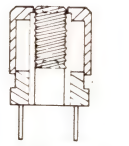
Solid magnet wire may be substituted for Litz wire, but somewhat lower 'Q' may result.

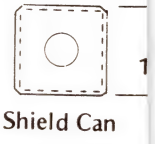
Frequency Range - 200kHz to 200mHz — Inductance Range 0.02 to 700 uH.

$$\text{Turns} = 100\sqrt{\frac{\text{desired 'L' (uh)}}{90\%\ A_L\ (\text{ uh/100 turns })}}$$

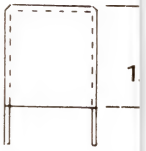


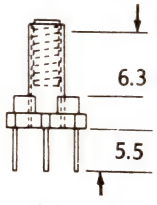
STOCK No.	AMIDON No.	Iron Grade & Colour Code	Frequency Range	A_L(μH/100t) at Max. L	L ratio Max. to Min.	Typical Winding (mid-freq.) Wire	Turns	LμH	Q Max.
FC594	L43-1	1 — Blue	300kHz - 1mHz	115	1.6/1	5/44	149	230	110
FC595	L43-2	2 — Red	1 - 10mHz	98	1.6/1	9/44	21	4	120
FC596	L43-3	3 — Gray	100 - 500kHz	133	1.8/1	3/44	223	600	90
FC597	L43-6	6 — Yellow	10 - 50mHz	85	1.4/1	26	6	.30	130
FC598	L43-10	10 — Black	25 - 100mHz	72	1.3/1	24	5	0.14	150


L43 with coil form

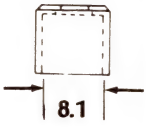


Terminal Spacing





Base



Cup Core

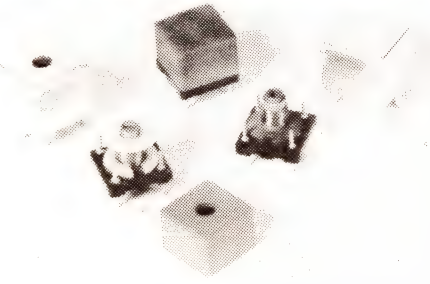
AMIDON L57 Series Shielded Coil Form Assemblies

Adjustable Inductors easly Wound on Shielded Coil Form Assemblies.

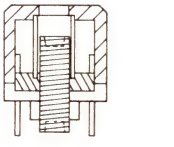
The AMIDON L57 series tunes from both top and bottom and is supplied as a kit comprising —; Shielding can (copper tin plated) - Cup core for magnetic shielding of same material as core for maximum efficiency at operating frequency - Core to provide adjustment of inductance - Nylon winding bobbin -Moulded plastic base with 6 contacts to accommodate centre tapped coils — five pieces in all.

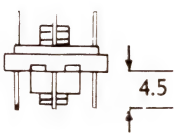
They are most efficient when tuning slug is set at maximum L. For tuning flexibility calculate so that slug will be about 90% maximum L when at operating frequency.

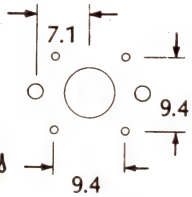
$$\text{Turns} = 100\sqrt{\frac{\text{desired 'L' (uh)}}{90\%\ A_L\ (\text{ uh/100 turns })}}$$



STOCK No.	AMIDON No.	Frequency Range	A_L (μ/100t) at Max. L	Iron Grade & Colour Code	Tuning Range
FC606	L57-1	300kHz - 1mHz	175μ½H	1 — Blue	3 / 1
FC607	L57-2	1 - 10mHz	125μH	2 — Red	2 / 1
FC608	L57-3	10 - 500kHz	204μH	3 — Gray	3 / 1
FC609	L57-6	10 - 50mHz	115μH	6 — Yellow	2 / 1
FC610	L57-10	25 - 100mHz	100μH	10 — Black	2 / 1
FC611	L57-12	50 - 150mHz	67μH	12 — Green	1.5 / 1







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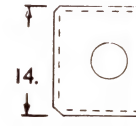

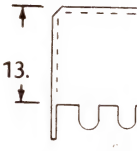

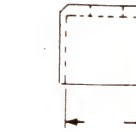

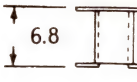

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If you are working at a lower frequency and thus require larger inductance values, the L57 assembly could be very useful. Apart from being physically larger than the L33 and L43 types, it also has a removable bobbin which facilitates other methods of winding. My method is to use a small hand drill clamped in a vice. Take a twist drill somewhat smaller than the inside hole of the bobboin and wind a strip of paper onto the drill in the opposite direction to the normal rotation. The bobbin can now be slipped over the paper and is held securely by twisting it against the direction in which the paper is wound. The windings can then be made by turning the drill whilst feeding the wire onto the bobbin and the result is a neat and even coil. The bobbin is easily removed by simply twisting it in the same direction as the paper which is wound on the drill.

The performance figures for all of the shielded assemblies are based on using them with the shield cup in place and the copper can assembled to the base. All of the copper cans are fitted with lugs which, when folded over the base, hold the entire assembly firmly in the can.

Pot cores

Whilst pot cores have many advantages, particularly for low frequency work, there are a couple of problems associated with their use. In the first place, they cost somewhat more than other former types and secondly, due to the large variety of material types, Al values and accessories, it is very difficult to find pot cores suitable for tuned circuits.

All the pot cores normally sold in electronics retail shops are what we call "ungapped" types. Because the ferrite material from which they are made is of a much higher permeability, it is possible to introduce an air gap into the centre post of the core assembly to reduce the specific inductance. In doing so, we can create a former capable of holding large amounts of wire by virtue of its large internal volume as well as possessing reasonable stability at the Al values concerned. Inductors so produced are capable of adjustment by introducing some ferromagnetic material into the gap in the centre post and are exceptionally well shielded.

The design of potcore inductors is a science in itself and is perhaps best left as the subject of a separate article.

The expensive alternative

There is one last way of obtaining the inductors you need for your filter – pay someone else to do it, or more precisely, buy pre-wound inductors. Pre-wound inductors are available in both fixed and adjustable types with values covering the range from 0.05 uH (50 nH) to 100 mH. Whilst many may prefer to roll their own, there are some who do not have the time to indulge in the pleasant, but sometimes frustrating pastime of winding coils. A selection of pre-wound inductors is shown in Figure 3 to give you an idea of what is available.

Useful hints

Early in this article, I mentioned that most cores are specified to operate at relatively low signal levels and with little or no dc bias on the winding. If you are designing filters for use at higher powers, you will need to use larger cores than those used at low levels as the power handling capability of a core is proportional to its volume.

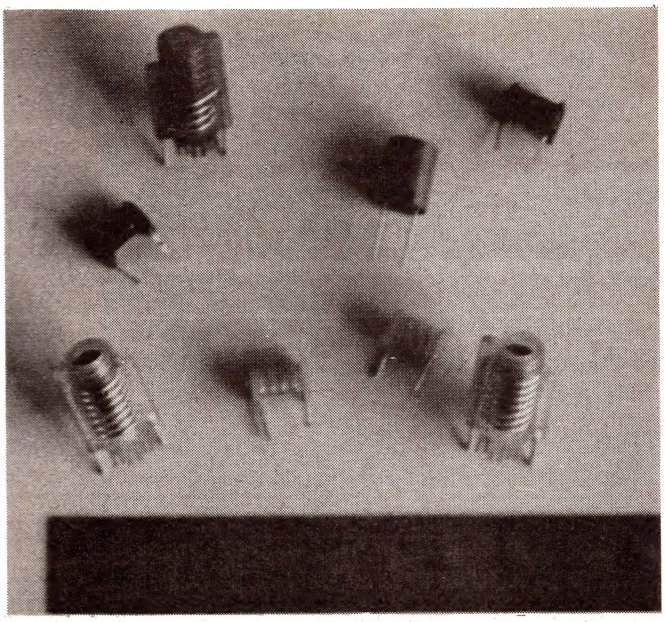

Figure 3. A selection of pre-wound coil assemblies.

The method of calculating the actual power handling capability of a particular core at a given frequency is not an easy one as a large amount of mathematics is involved. Because the iron powder materials have very high saturation flux densities, they actually lend themselves to high power operation. At radio frequencies, no information about saturation characteristics is available. However, you can use the following as a guideline:

T50 and T68 cores will handle up to 100 watts or so over the HF range.

T80 and T106 cores have been used at up to 1000 watts in low impedance applications.

T200-2 cores have been routinely used at 1000 watts plus as balun cores, but only to 100 watts in high impedance tank applications.

Most inductors wound on iron powder toroids can handle up to 500 mA dc without noticeable inductance changes on T50 size cores.

Hopefully you have now penetrated some way through the mystical veil surrounding inductor design. We hope that perhaps the information we have presented will help to make home construction more attractive and rewarding for you.

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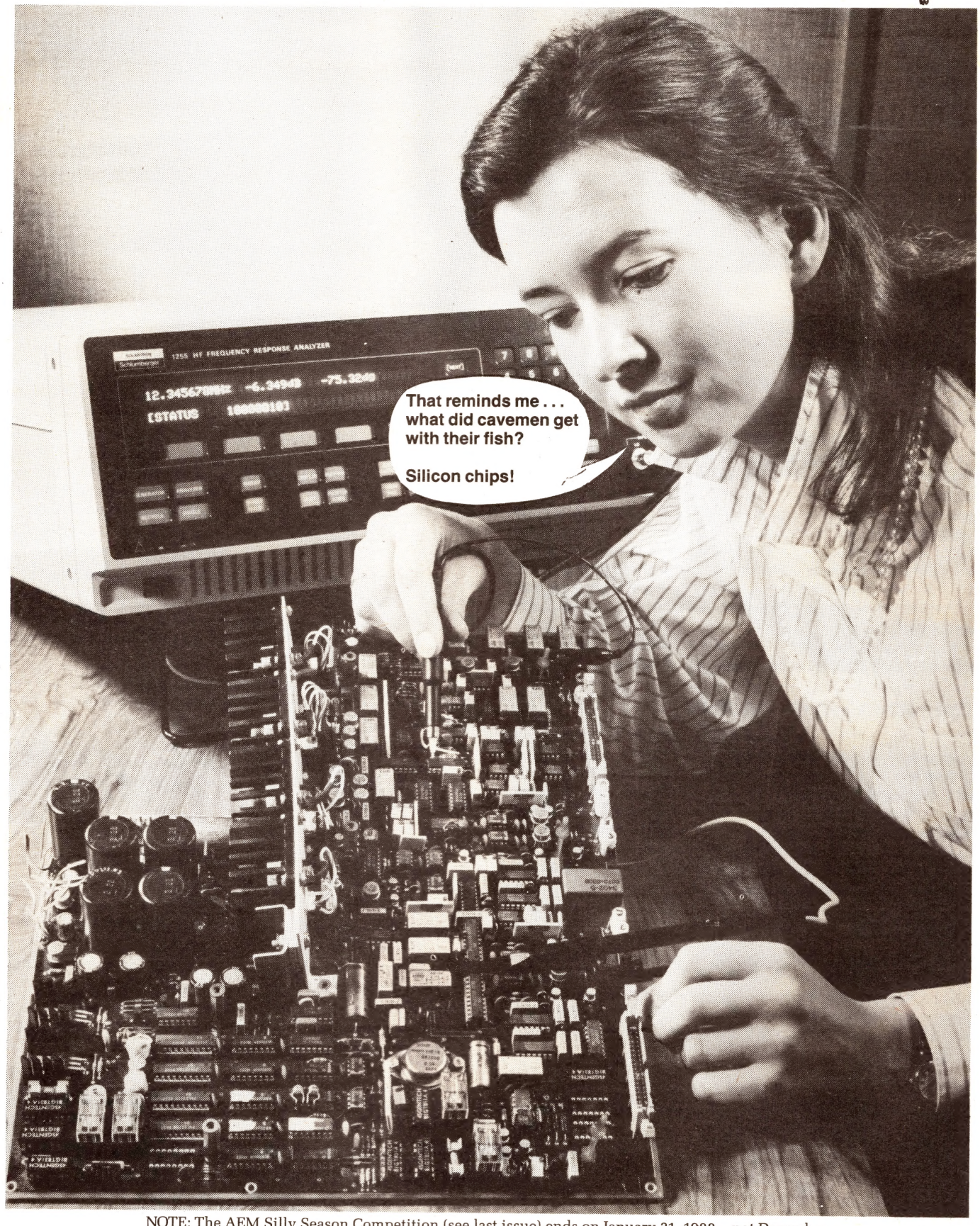
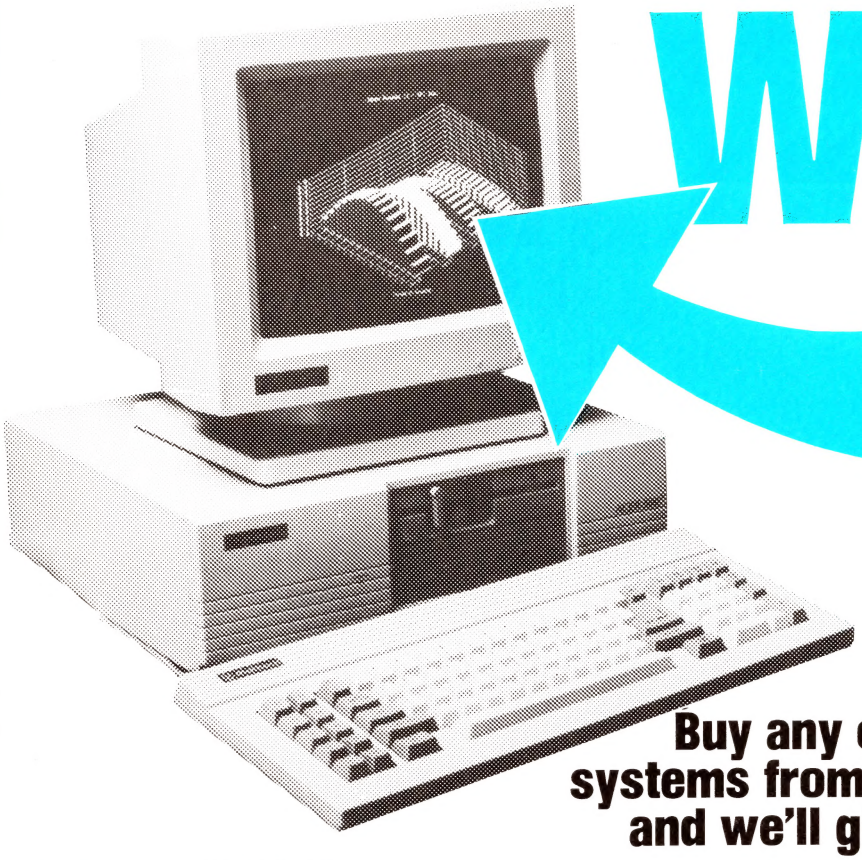


NOTE: The AEM Silly Season Competition (see last issue) ends on January 31, 1988 – not December. The prizes are genuine. We said it was the silly season!



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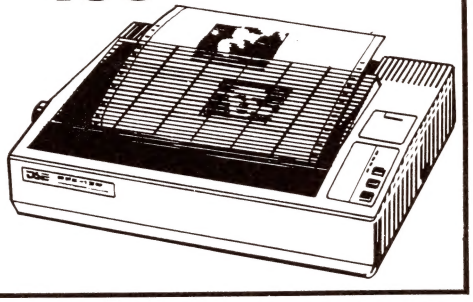

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